

Importation of Avocado Fruit (*Persea americana* Mill. var. 'Hass') from Mexico

A Risk Assessment

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Executive Summary

This risk assessment responds to a request to remove certain restrictions on the importation of ‘Hass’ avocados (*Persea americana* Mill. var. ‘Hass’) from the state of Michoacán, Mexico. Its purpose is to analyze the risks of expanding the Mexican ‘Hass’ avocado import program to authorize imports throughout the United States year-round. This assessment was thus prepared to assist APHIS in evaluating the above request to expand the scope of the existing Mexican ‘Hass’ avocado import program. APHIS phytosanitary regulations currently restrict fresh avocado imports to 31 northeastern and north central states, limiting distribution to October 15 through April 15, with the exception of Alaska receiving year-round imports.

This revision incorporates comments and data received during the 90-day public comment period June through September, 2003.

The main conclusions of this risk assessment are that, as a result of trade, carried out with the appropriate systems mitigations and safeguards:

- The most likely number of infested avocados entering the United States each year is zero.
- The most likely number of infested avocados entering avocado growing counties in the United States each year is zero.
- Less than 387 infested avocados will enter the United States each year, estimated with 95% confidence.
- Less than 49 avocados infested with stem weevil, seed weevils and seed moth will enter avocado producing areas each year, estimated with 95% confidence.
- Less than 143 avocados infested with fruit flies will enter fruit fly susceptible areas each year, estimated with 95% confidence.
- Less than 3 avocados infested with stem weevil, seed weevils and seed moth will be discarded in avocado producing areas each year, estimated with 95% confidence.
- Less than 8 avocados infested with fruit flies will be discarded in fruit fly susceptible areas each year, estimated with 95% confidence.
- There is an overall low likelihood of pest introduction.

The assessment lists all avocado pests known to occur in Mexico. After eliminating non-quarantine and non-pathway pests from the list, eight pests (three fruit flies: *Ceratitidis capitata*, *Anastrepha ludens*, *A. striata*; three seed weevils: *Conotrachelus aguacatae*, *C. perseae*, and *Heilipus lauri*; one stem weevil: *Copturus aguacatae*; and one seed moth: *Stenoma catenifer* are quarantine significant and may follow the avocado pathway. All of these pests are considered to have a low likelihood of introduction. Only the fruit flies would result in high-level consequences if introduced and established, and the other quarantine pathway pests would result in medium level consequences. The fruit flies are generalists as far as plant species attacked, whereas the other quarantine pathway pests would only affect avocado as a host in the United States.

Mitigation of the risk posed by the pests is accomplished by a systems approach. The systems approach for 'Hass' avocados imported from Mexico includes a set of independent, redundant, and overlapping phytosanitary measures that collectively reduce the risk of pest introduction into the United States. The first level of controls aims to monitor levels of target pests in the PRA area. Mandatory survey requirements are in place to detect infestations with a high degree of confidence. Exporting municipalities and orchards in Michoacán have been annually surveyed for six years with negative results for five of the pathway pests: *Ceratitis capitata*, *Heilipus lauri*, *Stenomoma catenifer*, *Conotrachelus aguacatae*, and *Conotrachelus perseae*. The stem weevil, *Copturus aguacatae*, was detected in seven surveys of orchards seeking to export to the United States over six years of surveillance. These seven detections were part of field surveys and not part of the export fruit dissection program described below. *Anastrepha* species were detected in adult bait traps numerous times over the last six years, but were never found to be infesting fruit. Those positive surveys resulted in mandatory pest eradication measures.

Part of this first level includes geographic and botanical restrictions. Fruits are only allowed from the PRA area, this area is restricted to the state of Michoacán, Mexico. The fruit is also restricted to the avocado cultivar 'Hass.' Research has shown *Anastrepha* spp. fruit flies have a low likelihood of being in the pathway, if the fruit remains healthy and attached to the tree. Fruit that falls from the tree is not permitted to enter the pathway. Culling is done to remove damaged or otherwise atypical fruit from the pathway.

Cutting and inspection of fruit is the second level of control designed to detect fruit infested with any of the quarantine pathway pests. Samples of fruit are collected in orchards, packinghouses, and ports of entry into the United States. No pests have been found in Mexican avocados in six years of fruit cutting and inspection. Over ten million fruit were examined (8.8 million in the orchards, 1.4 million in packing houses, and 117,750 at border inspection) for pests. If an infested avocado were to be found, a trace-back mechanism in the systems approach allows APHIS and Mexican authorities to identify the source orchard. These orchards would lose their export certification until appropriate pest eradication measures are completed.

The mitigations in the systems approach are designed to reduce the risk of pathway pests. The success of this approach is evident from the failure to detect even one pest or infested avocado, despite continuous and concerted efforts. Avocado importations during the last six years have provided APHIS with valuable experience managing the systems approach and increased the Agency's confidence in the efficacy of the safeguards.

In addition to analyzing the kinds of pests associated with avocado, APHIS analyzed the likelihood of introduction of these pests. Our approach included quantitative and descriptive elements based on the available scientific evidence. A quantitative analysis based only on the fruit cutting data predicts that the most likely number of

imported avocados infested with fruit flies, seed weevils, stem weevils, or seed moths is zero. Specifically, the most likely proportion of infested avocados was found to be zero. The 95% confidence interval ranged from 0 to 5.25×10^{-7} [that is, from 0 to 52.5/100,000,000].

The likelihood of introduction from imports may be compared to the number of smuggled or inadvertently imported avocados containing the quarantine pathway pests already entering the U.S, which is estimated at 150 to 300 per year. APHIS-PPQ data (PIN-309) indicate that pathway pests are routinely found in prohibited avocados intercepted in baggage and cargo at U.S. ports of entry. During the seventeen-year period from 1985 to 2002, an average of 30 avocados infested with pathway pests were intercepted and denied entry into the United States each year. Studies of port efficiency (Miller *et al.*, 1996; Meissner *et al.*, 2003) at finding prohibited materials suggest that inspectors detect approximately 10-20% of what actually arrives; this suggests that an estimated average 150-300 infested avocados are introduced each year through baggage and cargo. During the period 1985 to 2002, 512 pathway pests were detected in intercepted avocados (specific variety or cultivar not recorded) in baggage and cargo: *Anastrepha* spp.: 10; *Conotrachelus* sp.: 242; *Copturus* sp.: 5; *Heilipus* sp.: 38; *Stenomoma* sp.: 217. Prohibited avocados in baggage and cargo pose a substantially greater risk to U.S. agriculture than commercial imports of 'Hass' avocados from Mexico. Legalizing imports of avocados from Mexico could reduce smuggling of the commodity into the United States.

In addition to the likelihood of introduction of fruit flies from prohibited baggage, *Anastrepha ludens* has been recorded in southern Texas for the past decade. Thousands of fruit flies are trapped yearly in this area and are currently under an eradication program; however, no establishment beyond south Texas and to other growing regions in the United States has been observed. At this time (2004), *A. ludens* continue to be present in southern Texas, suggesting that the spread of *A. ludens* to production areas to the north is unlikely.

In the past, fruit flies (*Anastrepha* spp.) have been a major concern and a key focus of previous risk analyses. Recent research (Aluja, *et al.*, In Press a) conducted under laboratory conditions prompted a re-evaluation of the potential of *Anastrepha* spp. to infect 'Hass' avocados (Appendix C). Based on this research, ARS concluded that commercially produced 'Hass' avocados are very poor hosts for the *Anastrepha* spp. considered. Moreover, 'Hass' avocados produced and exported using the systems approach described in this document, have a low likelihood of being a pathway for *Anastrepha* spp. fruit flies.

Even if an infested avocado were to arrive at a region with host material, several additional conditions are required for pest establishment: (a) The pest must survive in the avocado during transportation and storage; (b) The infested avocado must be discarded in close proximity to host material; (c) The pest must find a mate; (d) The pest must successfully avoid predation and other threats; (e) The adult pest must find appropriate host material; and (f) Suitable climatological and microenvironmental

conditions must exist. Although information that would allow quantifying these conditions is not currently available, collectively they substantially reduce the likelihood of pest establishment and the overall level of risk.

We note that as illustrative as are the results of the quantitative analysis, they do not provide an expression of “risk” as an endpoint. The quantitative analysis estimated the probability that infested fruit reach production areas; *introduction* requires additional steps (identified as “a” through “f” above) and is described here in qualitative terms, as “low”. Risk-reducing effects of the systems approach are evidenced in USDA’s experience with the program and fruit sampling information. Repeated surveys, inspections, and other requirements of the systems approach reduce risk substantially. Confidence in these surveys and inspections is reinforced, first, by repeated site visits by APHIS personnel; second, by the active participation of APHIS field personnel in the surveys; third, by the redundancy of the systems approach mitigations; and fourth, by the fact that examination of over ten million fruit has not revealed any pests.

The mitigations in the systems approach are designed to reduce the risk from pathway pests. The effectiveness of this approach is evident from the failure to detect arthropods in even one avocado in the commercial pathway to the United States, despite very large samples and continuous, concerted survey and detection efforts. Avocado importations during the last six years have provided APHIS with valuable experience managing the systems approach. APHIS concludes that the modified systems approach will remain effective if the program is expanded.

Introduction

This risk assessment responds to a request by Mexico to remove certain restrictions on the importation of fresh avocado (*Persea americana* Mill var. 'Hass') fruit from Michoacán, Mexico; its purpose is to analyze the risks of expanding the existing Mexican 'Hass' avocado import program to authorize imports to all states year-round. This assessment was prepared to assist APHIS in evaluating the request to expand the scope of the existing import program. APHIS regulations currently restrict avocado imports to 31 northeastern and north central states, Alaska, and the District of Columbia. Shipment and distribution are allowed only from October 15 to April 15. This plant pest risk assessment evaluates the importation of fruit to the entire United States throughout the year. Whereas the current system is used as a reference point, this assessment focuses on the risks associated with a program that will be expanded geographically and referred to as a modified systems approach.

This assessment first identifies and lists all pests of potential importance to the United States associated with avocados in Mexico (Appendix A). Non-quarantine and non-pathway pests are then eliminated from further consideration. The assessment next estimates the likelihood of introduction for the remaining pathway pests. Two quantitative endpoints of the likelihood of introduction of pathway pests are estimated: the number of infested avocados entering the United States each year and the number of infested avocados entering avocado producing regions in the United States each year. Given an importation of an infested avocado, the additional steps leading to pest establishment and spread ("introduction", in terms of the International Plant Protection Convention) are evaluated using qualitative evidence. Finally, the consequence of introduction is considered.

This document does not attempt to address the level of pest infestation that constitutes acceptable or negligible risk; however, information on the number of quarantine pathway pests found on other pathways, prohibited fruit in travellers' baggage and prohibited cargo entering the United States is provided for comparison. Also, to provide context, the infestations of *Anastrepha* fruit flies in south Texas over the past decade have been cited.

APHIS has completed several risk assessments of avocados imported from Mexico (USDA 1995, 1995a, 1996, APHIS 2001b, c). This document updates and supplements evidence presented in those assessments. This assessment also considers new evidence regarding the potential for *Anastrepha* fruit flies to infest 'Hass' avocados, and the results of avocado inspections completed by Mexican and APHIS officials. Key elements of previously published risk assessments and other APHIS documents are presented within the document in order to permit the reader to understand this analysis without reference to previous work. Some elements, however, are incorporated by reference; the relevant documents are available on the Internet at: <http://www.aphis.usda.gov/ppq/avocados/>.

History of Avocado Importation from Mexico

Quarantine 56 (7 CFR § 319.56) provides general regulatory authority for the importation of fruits and vegetables. In 1973, the specific avocado quarantine was incorporated into the general nursery stock (7 CFR § 319.37) and fruit and vegetable quarantines (Quarantine 56, 7 CFR § 319.56).

USDA has restricted the importation of Mexican avocado fruit since 1914 in order to protect the phytosanitary health of U.S. avocado production. The primary justification for the 1914 restriction was the presence of an avocado seed weevil (*Heilipus lauri*) in Mexico (Table 1). Since 1914, Mexican agricultural officials and exporters, as well as U.S. importers of agricultural commodities, have repeatedly petitioned for authorization to import Mexican avocado fruit into the United States.

Table 1 - Chronology of Mexican Avocado Importation

Year	Event
1914	APHIS prohibits importation of avocados from Mexico because of seed weevils.
1993	APHIS amends rule to allow entry of Mexican avocados into Alaska under certain conditions.
1997	APHIS amends rule to allow entry of Mexican avocados from Michoacán, Mexico to 19 northeastern states from November to February, subject to certain phytosanitary requirements.
2001	APHIS amends rule to allow entry of Mexican avocados from Michoacán, Mexico to 31 northeastern and north central states from October 15 through April 15, subject to certain phytosanitary requirements.
2003	APHIS publishes draft risk analysis associated with exports of Mexican Hass avocados from Michoacán to all 50 states and during the entire year.

In 1992, Mexican authorities asked APHIS to consider allowing the importation of ‘Hass’ avocados from Mexico to any destination in the United States. APHIS conducted a risk assessment and concluded that Mexican avocados could be safely imported into Alaska because imported pests could not survive or establish there. That assessment used a decision sheet format (Attachments 1 and 2 of Risk Management Analysis: A Systems Approach for Mexican Avocados, APHIS, 1995b). A proposed rule was published in the Federal Register in 1992 (APHIS, 1992) and the final rule was published the following year (APHIS, 1993a). At the current time, ‘Hass’ avocados from Michoacán can be imported to Alaska under the conditions specified in 7CFR§319.56-2bb.

Interest in the exportation of Mexican avocado fruit to other states continued after 1993 with Mexico making repeated requests. APHIS formed an oversight group to consider Mexico’s requests. The APHIS Oversight Group met several times and made three trips to the Mexican avocado growing areas in Michoacán, Mexico. APHIS developed two documents relevant to avocado imports: *Potential Economic Impacts of an Avocado Weevil Infestation in California* (APHIS, 1993b), and *Economic Impact of the Establishment of Mexican Fruit Fly in the United States* (APHIS, 1993c).

In July 1994, Sanidad Vegetal, the plant protection branch of the Mexican Ministry of Agriculture and Water Resources, requested that APHIS allow Mexico to export fresh ‘Hass’ avocados from approved orchards in approved municipalities in Michoacán into the northeastern United States. After reviewing Mexico’s proposal, APHIS published an *Advance Notice of Proposed Rulemaking* (59 FR 59070-59071, Docket

No. 94-116-1) in the *Federal Register* (November 15, 1994) announcing APHIS' receipt of the request. APHIS officials prepared two documents as part of the risk analysis. The first document, "Risk Management Analysis: A Systems Approach for Mexican Avocado," (USDA, 1995b), is an analysis of the procedures to reduce pest risk associated with Mexican 'Hass' avocados. The second document "Importation of Avocado Fruit (*Persea americana*) from Mexico: Supplemental Pest Risk Assessment" (USDA, APHIS, 1995a) includes a quantitative assessment of the likelihood of introducing certain pests, as well as an assessment of the consequences of introduction. The assessment estimated that the risk was low with a systems approach in place (*i.e.*, a systems approach as described in <http://www.aphis.usda.gov/ppq/avocados/>). A final rule was published in the *Federal Register* in February, 1997 to allow the importation of fresh 'Hass' avocados from Mexico under certain conditions. The 1997 rule allowed imports of avocados to nineteen northeastern states (Connecticut, Delaware, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin), and the District of Columbia, but limited shipments to the months of November through February. Climatic conditions in those states during the winter months precluded the establishment of any exotic plant pests that might accompany avocados from Michoacán, Mexico.

In September 1999, the Government of Mexico requested that APHIS further expand the importation of 'Hass' avocados into the United States in accordance with the Sanitary and Phytosanitary (SPS) agreement and the North American Free Trade Agreement (NAFTA). APHIS considered the request and finalized the current rule for avocado importation from Mexico in 2001. Under the regulations (7CFR Sec. 319.56-2ff) avocados are currently allowed to enter 31 states and the District of Columbia from October 15 through April 15 of the subsequent year. The current importations are subject to a series of mitigations, described in "Risk Management Analysis: A Systems Approach for Mexican Avocados" (USDA, 1995b, available at: <http://www.aphis.usda.gov/ppq/avocados/>). Under the regulations (7CFR Sec. 319.56-2bb) avocados may be imported into Alaska throughout the year under less restrictive conditions.

Key Safeguards on the Importation of Mexican Avocados

The importation of Mexican avocados is managed using a “systems approach.” This refers to a set of independent, redundant and overlapping phytosanitary measures that collectively mitigate the risk of pest introduction into the United States (Anonymous, 2002; and NAPPO Glossary of Phytosanitary Terms). The systems approach is described as the integration of different pest risk management measures, at least two of which act independently, and which reduces the risk of pest introduction (FAO, 2002). The systems approach for ‘Hass’ avocados has successfully protected U.S. agriculture for several years from pests potentially associated with this pathway. Avocado importations during the last six years provided APHIS with valuable experience managing the systems approach and increased the Agency’s confidence in the efficacy of the safeguards.

Key safeguards in the systems approach are listed in Table 2 and described below. The expanded distribution of avocados requested by Mexico will eliminate two components (components 6 and 9, Table 2), allowing avocados to enter all fifty states year-round.

1. Field surveys

Current regulations (7 CFR § 319.56-2ff (c) (ii)) and the proposed modification to the systems approach require annual surveys of orchards and municipalities.

Municipality Surveys

Only certain municipalities of Michoacán are qualified for the export program (http://www.aphis.usda.gov/ppq/avocados/workplan_2003.pdf). Current regulations and the proposed systems approach require the

Government of Mexico, along with APHIS, to conduct annual area surveys of Michoacán municipalities for *Ceratitis capitata*, *Heilipus lauri*, *Stenomacrus catenifer*, *Conotrachelus aguacatae* and *Conotrachelus perseae* before they can become certified to export fruit. Certification is dependent upon pests being absent from the municipalities. The *Ceratitis capitata* survey must include a trap every one to four square miles (7 CFR§319.56-2ff (c)(1)(ii) and (iii)). For *Heilipus lauri*, *Stenomacrus*

Table 2. Components of the Current and Modified Systems Approaches for Avocados imported from Mexico

Current Systems Approach	Modified Systems Approach
1. Field Surveys (municipalities and orchards certification, pest free status, Michoacán only)	Field Surveys (municipalities and orchards certification, pest free status, Michoacán only)
2. Trapping Activities	Trapping Activities
3. Field Sanitation	Field Sanitation
4. Host Resistance (‘Hass’ cultivar only)	Host Resistance (‘Hass’ cultivar only)
5. Post-Harvest Safeguards (transport to packinghouse in screened trucks within three hours of harvest, shipping in refrigerated containers)	Post-Harvest Safeguards (transport to packinghouse in screened trucks within three hours of harvest, shipping in refrigerated containers)
6. Winter Shipping Only (Oct 15 – April 15)	No restriction on shipping season
7. Packing House Inspection, Culling, and Fruit Cutting	Packing House Inspection, Culling, and Fruit Cutting
8. Port-of-Arrival Inspection and Clearance Activities	Port-of-Arrival Inspection and Clearance Activities
9. Limited Distribution (31 states and the District of Columbia)	No restriction on distribution. Requirement for sealing trucks during transport within the United States removed

catenifer, *Conotrachelus aguacatae* and *Conotrachelus perseae*, the surveys must cover at least 300 randomly selected hectares in each municipality and include portions of commercial orchards, wild areas and backyards. The surveys include foliage sampling, fruit cutting, and visual inspection. Foliage samples are collected by beating the lower branches of a tree over a white tarpaulin. Foliage and other material falling onto the tarpaulin are examined for pests. The survey must be conducted during the growing season and completed prior to the harvest of the avocado. The survey sampling method is calibrated to detect pests if they are present in one percent or more of the area surveyed at a 95% confidence level (USDA, 1995b; http://www.aphis.usda.gov/ppq/avocados/workplan_2003.pdf).

Six years of surveys found no evidence of *Heilipus lauri*, *Stenoma catenifer*, *Conotrachelus aguacatae* and *Conotrachelus perseae* in Michoacán municipalities certified to export to the United States (Tables 5a and 5b). *Stenoma catenifer*, *Conotrachelus aguacatae*, and *Heilipus lauri* have not been found in Michoacán (USDA, 2001b). The seed weevil, *Conotrachelus perseae*, occurs only in one small area of Michoacán near Ziracuaretiro. Mexico has quarantined this area and conducted an eradication program for the past three years during which time the quarantined area has been reduced from 600 to 140 acres (USDA, 2001b). (The municipality of Ziracuaretiro is currently not in the export program.) It should be noted that if quarantine pests are found, those areas are eliminated from the export program and eradication programs initiated.

APHIS monitors Mexico's compliance with municipality survey procedures in Michoacán. If *Ceratitidis capitata*, *Heilipus lauri*, *Stenoma catenifer*, *Conotrachelus aguacatae* or *Conotrachelus perseae* are detected, the affected municipality would lose its pest-free certification. Sanidad Vegetal is required to inform APHIS about any infestations and control/eradication measures commence and avocado exportation from the municipality involved is suspended. Exports could resume only if and when APHIS determines that Mexico had implemented effective measures and eradicated the pest from the infected municipality (Appendix E).

Orchard surveys

Certification of orchards in the export program requires participation in a multi-level pest inspection and approval process. The certification process begins when a grower petitions the Junta Local de Sanidad Vegetal (JLSV - the local equivalent to a U.S. county agricultural office) to participate in the export program. Inspectors from the JLSV office visit the prospective orchard biweekly and conduct general pest inspections. After the JLSV inspector identifies the pest-free export-eligible orchards, the Comité Estatal de Sanidad Vegetal (CESV - equivalent to a state agricultural office in the U.S.) inspects the orchards once again, and certifies that it is free from the pathway pests. Orchards that pass this inspection are approved to export for the following season. APHIS and CESV inspectors conduct a third inspection the following year during the avocado growing season. Final approval to export is only given after an orchard is determined to be free of pathway pests in all three inspections.

(Appendix E).

Fruit are cut and inspected for pathway pests in the orchards during the surveys. A total of 8.8 million avocados from export orchards have been inspected over the past six years (an average of 1.4 million avocados per year) and no pathway pests have been detected.

APHIS monitors compliance with orchard survey requirements and APHIS personnel participate in the annual surveys. The current and proposed modified systems approaches require Mexican authorities to conduct annual surveys of orchards for the stem weevil, *Copturus aguacatae*. If the stem weevil is detected, the affected orchard is denied export certification for the entire shipping season. Exports can resume only when APHIS determines that Mexico has implemented effective measures and eradicated the pest from the infected orchard (Appendix E). During the past six years of surveillance, stem weevils have been detected in five orchard surveys.

2. Trapping

Authorities must continuously use McPhail traps to monitor for *Anastrepha ludens*, *A. serpentina*, and *A. striata* (Appendix E). If *Anastrepha* species are detected in traps, an additional 10 traps must be deployed in the surrounding 50 hectares. If another fruit fly is found, malathion bait spraying must be done every 7-10 days in the affected orchard for the orchard to remain in the program. Recent research has demonstrated that commercial ‘Hass’ avocados are very poor hosts for the above *Anastrepha* species and *A. obliqua*-(Appendix C).

3. Field sanitation practices

The current and proposed modified systems approach requires orchard sanitation measures (Appendix E). Dead branches on avocado trees must be pruned. Fallen fruit must be collected and removed weekly. Fallen fruit, which are usually overripe or damaged, are more susceptible to pest infestation, including fruit flies (*Anastrepha* spp.). Pruning helps to prevent infestations of the stem weevil (*Copturus aguacatae*) (USDA, 1995b). Field sanitation measures are intended to maintain healthy orchards, thus reducing their susceptibility to pest infestation.

Field sanitation practices are the responsibility of the avocado grower or orchard owner. Junta Local de Sanidad Vegetal (JLSV) monitors compliance. Sanidad Vegetal and APHIS assess field sanitation practices during annual orchard surveys.

4. Host resistance

The natural resistance and very poor host status of ‘Hass’ avocados to certain *Anastrepha* spp. found in Mexico was, and will continue, to be used as a safeguard. A discussion of the effectiveness of this safeguard can be found in Appendix C. ‘Hass’ avocados are easily distinguishable from other varieties by their pebbly skin texture, characteristic shape and size, and black color when ripe. (Other varieties are smooth and green.) Accidental or deliberate substitution of other varieties is unlikely and can be easily detected.

5. Post-harvest safeguards

The following requirements will be maintained in the proposed modified systems approach (Appendix E).

In the orchard, avocado field boxes must be marked with the registration number of the orchard (7CFR§319.56-2ff(c)(2)(v)). At the packinghouse, the identity of the orchard must be maintained from the field boxes to the shipping containers (7CFR§319.56-2ff(c)(3)(vii)). Prior to packing in boxes, each avocado must be labeled with the registration number of the packing house. In addition, avocados must be packed in boxes marked with the identity of the grower, packinghouse, and exporter. If a pest were found in an avocado at any point from the packinghouse to the market, APHIS and Sanidad Vegetal could determine the orchard where it was grown. Although no pathway pests have been detected in the past six years, this trace-back mechanism is an important safeguard designed to allow APHIS and Mexican authorities to determine the cause of a breakdown in the systems approach and respond with appropriate measures.

A phytosanitary certificate issued by Sanidad Vegetal certifying that the conditions specified in the regulations have been met must accompany all shipments of avocados. Shipments are safeguarded during transit and inspected upon arrival at their port of entry, certificates are then checked by DHS (Department of Homeland Security) inspectors. These measures ensure that the fruit shipments originate from certified orchards and are managed in accordance with the requirements generated by the systems approach.

The current and proposed modified systems approaches require transportation of avocados in refrigerated trucks or containers. In addition, avocados are refrigerated during storage as part of normal retail marketing and fruit distribution. Optimum storage temperatures for 'Hass' avocados range from 5° to 8°C (www.postharvest.com.au/Avocado_Hass.pdf). Insects develop very little, if at all, from below 4 - 10°C (http://www.ento.vt.edu/Fruitfiles/Understanding_Degree_Days.html), as they commonly exhibit high mortality at the lower storage temperatures (Stinner *et al.*, 1974; Wagner *et al.*, 1984).

6. Winter Shipping

The current rule limits the shipment and distribution of Mexican avocados to the timeframe between October 15 and April 15 (7 CFR § 319.56-2ff (a) (2)). This restriction would be removed in the proposed modified systems approach.

7. Packinghouse inspection and fruit cutting

The packinghouses in Mexico that process avocados for export to the United States must be registered with Sanidad Vegetal and listed in their annual work plan provided to APHIS. The requirements for packinghouses specified in the current rule include several mitigations designed to exclude fruit flies, detect infested avocados, and allow

trace-back if infested avocados are found.

Avocados must be moved from the orchard to the packinghouse within three hours of harvest or covered to exclude pests (7CFR§319.56-2ff((c)(2)(v)). During shipment to the packinghouse, the avocados must be covered or enclosed. At the packinghouse, screens are required on windows and double doors on entrances (7CFR§319.56-2ff((c)(3)(ii)). These measures are designed to exclude fruit flies (*Anastrepha* spp.). Although 'Hass' avocados are very poor hosts for the fruit fly species commonly found in Mexico, some evidence suggests *Anastrepha* spp. may be able to infest avocados several hours after they are picked (Appendix C).

Stems and leaves must be removed from the fruit prior to being packed in boxes. This requirement helps to ensure that pests infesting parts of the plant other than the fruit are excluded from the shipment.

Inspectors in the packinghouses inspect and cut fruit sampled from shipments for the presence of pathway pests. In practice, this is accomplished by sampling fruit from each field truck arriving at the packinghouse from the orchard that will go into a shipment. Cutting typically involves making multiple thin slices completely through the fruit, including the seed. Sanidad Vegetal inspectors have examined nearly 250,000 avocados per year this way for the past six years. A total of 1.5 million avocados were examined; no pests were found.

Packinghouses must label each fruit with a sticker that states the registration number of the packinghouse, while boxes or crates must be marked with the identity of the grower, packinghouse, and exporter. The identity of the avocados must be maintained from field boxes or containers to the shipping boxes so the avocados can be traced back to the orchard in which they were grown if a pest was found at the packinghouse or the port of first arrival in the United States.

Another post-harvest requirement is the refrigeration of trucks from the packinghouse to US markets (7 CFR§319.56-2ff(3)(c)(viii)). At the packinghouse, boxes must be placed in a refrigerated truck, or refrigerated container, and remain in that truck or container while in transit through Mexico to the United States. Prior to leaving the packinghouse, Sanidad Vegetal must secure the truck or container with a seal that will be broken if the truck or container is opened. Once sealed, the refrigerated truck or container must remain unopened until it reaches the United States. The mortality effect of refrigeration on the pathway pests has not been determined, but is expected to be a significant, additional safeguard.

8. Port-of-arrival inspection

Mexican avocados currently enter the United States at designated locations. DHS inspectors ensure that the seals on the trucks are intact upon arrival and that the shipment is accompanied with a phytosanitary certification issued by Sanidad Vegetal certifying compliance with all provisions of the rule.

At the port of first arrival DHS inspectors must inspect avocados from each shipment for pests (7CFR § 319.56 – 2ff (d)). According to the AQIM Handbook (PPQ, 2003) sampling was devised to provide a 95% probability of detecting pests present at a 10% infestation rate per shipment. Currently, DHS inspectors sample one fruit per box from 30 boxes per shipment. DHS (formerly APHIS) inspectors have examined approximately 20,000 avocados, which is approximately a total of 120,000 avocados for the past six years.

9. Limited Distribution

Shipments are currently limited, but will be expanded to 50 states under the proposed modified systems approach.

Summary of Key Safeguards

Surveys for pathway pests in municipalities and orchards, orchard certification, host plant resistance, protection of harvested fruit from infestation, and shipment in sealed, refrigerated trucks are the first line of defense in preventing pests from entering the import pathway. Inspection of fruit at packinghouses and ports of entry is a secondary line of defense. In addition, fruit are cut and inspected in orchards, packinghouses, and ports of arrival in the United States. If a pathway pest is detected, APHIS and Mexican officials can trace back to the orchard of origin to determine the cause of the breakdown and take corrective action. In six years of imports, no pathway pests have been detected in certified harvested fruit in the import pathway as ascertained by sampling more than ten million fruit at the border.

Summary of Risk Analysis-Related Activities

APHIS conducted a risk management analysis for Mexican ‘Hass’ avocados in 1995; this analysis (USDA, 1995, a, b) described the degree to which various elements of the systems approach are expected to mitigate the pest risk associated with such importations. The analysis concluded that the cumulative effects of the systems approach lowered the risk of all target pests and that even if one of the mitigation measures should completely fail, the effect of the other measures would maintain a low level of risk.

In 2001, APHIS again reviewed the Mexican ‘Hass’ avocado import program in response to a request from the California Avocado Commission (USDA, 2001b; <http://www.aphis.usda.gov/ppq/avocados/#support>). As part of the review, a team of APHIS officials visited avocado production areas in Michoacán, Mexico. The site visited by the team observed trapping and orchard sanitation practices in Michoacán and concluded that the program was operating in compliance with the regulations. Also, the USDA review team visited one of ten agricultural quarantine highway checkpoints on the border of one of the approved municipalities staffed by Comité Estatal de Sanidad Vegetal (CESV). All fruit trucks must stop at these checkpoints, both entering and leaving the municipalities, to verify documentation and contents of the truck. The agricultural inspectors make random checks of passenger vehicles and non-fruit trucks entering the municipalities as a phytosanitary measure to maintain

freedom from avocado pests not known to occur in the municipality. The review team concluded that the surveillance activities used in Mexico for area and production site approvals complied with 7 CFR § 319.56-2ff. JLSV's biweekly year-round surveys in export orchards, CESV's yearly spring surveys from March through June of avocado export orchards, backyard avocado trees and wild avocado trees, and the joint APHIS/CESV summer survey from July through September have been adequate to meet the surveys required in 7 CFR § 319.56-2ff(c)(1)(ii), 7 CFR § 319.56-2ff(c)(2), and 7 CFR § 319.56-2ff(c)(2)(i).

The report of the review group may be summarized as follows (USDA 2001b):

- The stem weevil, *Copturus aguacatae*, occurs in Michoacán and in municipalities having orchards that export to the U.S.
- The seed weevil, *Conotrachelus perseae*, occurs in Michoacán, but not within exporting municipalities. In Michoacán, it occurs only in one small area near Ziracuatiaro—this area is under an eradication program and has been a quarantined area, although it has been reduced from 600 acres to 140 acres.
- The seed weevils, *Conotrachelus aguacatae* and *Heilipus lauri*, are not known in Michoacán.
- The seed moth, *Stenoma catenifer*, probably does not occur in Michoacán and would likely be detected by current sampling systems.

Following requests from the Mexican government in 2001-2002, APHIS prepared an initial draft of the present risk analysis document (published on the APHIS website June 2003). After a 90-day public comment period (60-day comments plus a 30-day extension), APHIS updated the PRA to reflect the input received, as follows:

-Fruit flies are analyzed for their consequences of introduction, although it is not likely that they are in the pathway. This was done because comments noted that some types of avocados (not related to the commercial 'Hass' variety) may be infested by fruit flies. Since a majority of the comments included concerns with fruit flies, APHIS decided that the fruit flies should be further analyzed, although scientific evidence suggests that Hass avocados are a very poor host.

-The pest list was modified but no new quarantine pathway pests were added.

-Several refinements to the quantitative analysis of the likelihood of introduction of infested avocados are included, but the revised analysis did not lead us to change our conclusions relative to the risks associated with the quarantine pests considered.

-Interpretation of the host status of 'Hass' avocado and *Anastrepha* spp. fruit flies, based on a review USDA-ARS of research, are now incorporated. This analysis was also expanded and revised to acknowledge and incorporate recommendations communicated by USDA-ARS (ARS, 2004; Appendix F).

Pathway Analysis

This risk assessment was pathway-initiated, meaning that the assessment was initiated in response to the request by the Mexican government to export a particular commodity, avocados.

The approach taken in this assessment was to first identify all Mexican avocado pests.

From this initial list, non-quarantine pests (as defined by NAPPO and IPPC above) were eliminated. From the list of quarantine pests, those pests that were not normally found on the plant part proposed for export (*e.g.*, those pests that would infest only roots) were eliminated. The likelihood and consequence of introduction was then estimated for the remaining pests. These steps include the three stages of the IPPC guidelines, plus additional detail consistent with the IPPC standards (APHIS, 2000; FAO, 1995; FAO, 2002):

1. Assessment of the weed potential of avocados.
2. Development of a pest list.
3. Identification of quarantine pests.
4. Identification of pathway pests for further consideration.
5. Estimation of the likelihood of introduction of the pests that are both quarantine and pathway pests under the conditions specified.
6. Estimation of the consequences of introduction.

In this document we address each of these six steps.

Assessment of Weed Potential of Avocado

The initial step after receiving a request for the importation of a commodity is to analyze the weed potential of the commodity itself. The process of evaluating the potential of avocados to become weeds is shown in Table 3. We found that the weed potential of avocado was low and the table details the evidence used in making this determination. Avocados of many cultivars, including ‘Hass’ are currently grown in several areas of the

Table 3 – Weed Potential of Avocado

Species: Avocado, *Persea americana*

To determine weed potential we followed the format below.

Is the species listed in:

NO *Geographical Atlas of World Weeds* (Holm, 1979)
NO *World's Worst Weeds* (Holm, 1977)
NO *Report of the Technical Committee to Evaluate Noxious Weeds; Exotic Weeds for Federal Noxious Weed Act* (Gunn & Ritchie, 1982)

NO *Economically Important Foreign Weeds* (Reed, 1977)

NO Weed Science Society of America List (WSSA, 1989)

NO Is there any literature reference indicating weed potential (*e.g.*, *AGRICOLA*, *CAB*, *Biological Abstracts*, *AGRIS*; search "avocado" combined with "weed" or "weediness").

IF: All of the above answers are no,

THEN: It is concluded that avocado is not a weed, and a weed risk assessment is not needed; therefore, the PRA may proceed (APHIS, 2000).

United States for fruit production (Appendix D, Table 6), in addition to being marketed as landscape plants.

Pest List

We identified all Mexican avocado pests with potential economic importance in the United States [Appendix A, tables A-1 (pathogens) and A-2 (arthropods)]. These lists were generated through the review of the following references and resources:

- Literature reviews using the AGRICOLA and CABPEST databases.
- Previous decision sheets covering the importation of avocados from Mexico, Jamaica, and Central America.
- The United States catalogue of intercepted pests and interception records.
- C.M.I. Distribution Maps and Descriptions of Plant Pathogenic Fungi and Bacteria.
- Texts and indices of plant pests and pathogens as listed in the bibliography section at the end of this assessment.
- APHIS' files on pests not known to occur in the United States (*e.g.*, PNKTO's "Pests Not Known to Occur" and INKTO's "Insects Not Known To Occur").
- Results kept by APHIS of annual orchard certification pest surveys in Mexico.

All pests listed in Table A-1 and A-2 are present in Mexico. The following information is given in the tables:

- Whether or not the pest occurs in the U.S.
- Information on the biology and regulatory history (*e.g.*, APHIS interception records); all pests intercepted at U.S. ports on avocado fruit from Mexico are included on the pest list.
- Selected references on the biology/distribution of each pest.

Identification of Quarantine Pests

From the list of Mexican avocado pests identified in the analysis, all those that were not "quarantine" pests were eliminated. A quarantine pest is "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (FAO, 1995; NAPPO/FAO, 1991). The distribution of each pest was reviewed to determine if any official control programs exist. Only those pests that were absent from the United States, or present, but not widely distributed or officially regulated fit the international standard for quarantine pests.

In tables A-1 and A-2 of appendix A, "MX" in the Distribution column indicates that the pest is present in Mexico and not in the United States (unless a state is identified in the same column, using the two letter state abbreviation) and is, therefore, a quarantine pest. Of the 26 pathogens listed in table A-1 (Appendix A), three do not occur in the United States (Two other pests are not identified to species and could be in the United States. If they are identified, they could be re-analyzed for quarantine significance in the future [APHIS, 2000]). Of the arthropods in table A-2 (Appendix A), 45 are quarantine pests.

Identification of Pathway Pests

From the list of quarantine pests, we eliminated those pests that are unlikely to follow

the pathway prior to mitigation by the modified systems approach, including cultivar resistance. Later in the analysis, the likelihood that fruit flies and other quarantine pests listed as in the pathway will remain in the pathway after mitigation is evaluated after the biology of each pest was reviewed to determine if the pest was associated with the fruit. The pathway of those pests that could not reasonably be expected to remain with the fruit after harvesting and packinghouse processing were eliminated (APHIS, 2000).

No quarantine pathogens (Table A-1) are considered to be in the pathway.

Of the arthropod pests listed in Table A-2, fruit flies deserve special note. Previous assessments (APHIS, 1995a) considered certain *Anastrepha* species as pests likely to be associated with avocado fruit. Those earlier assessments concluded that avocados were either non-hosts or at best, poor hosts, and that the probability of association of *Anastrepha* spp. with the ‘Hass’ avocado imports was low (USDA, 1995a). In the present document, *Anastrepha ludens*, *A. striata*, and *Ceratitis capitata* are listed in Table A-2 as being in the pathway before mitigation. The field survey infestation records (Liquido *et al.*, 1998; Norbomm, In Press; Norbomm and Kim, 1988) were recognized as evidence for listing those fruit flies in the pathway of unspecified varieties before mitigation.

Aluja *et al.* (In Press a) noted ‘Hass’ avocados on the tree, or within three hours after harvest, a “non-host” for *Anastrepha ludens*, *A. obliqua*, *A. serpentina*, and *A. striata*. The protocol developed by Cowley, *et al.*, (1992) was followed by Aluja *et al.* (In Press a) to determine if commercial ‘Hass’ avocados are natural hosts (Appendix C). In laboratory and field trials, ‘Hass’ avocados were naturally and artificially exposed to large numbers of fertile pairs of four different species of *Anastrepha*: *A. serpentina*, *A. ludens*, *A. striata*, and *A. obliqua*. The conditions of exposure included both choice studies and no-choice studies. The choice studies included ‘Hass’ avocados and other hosts. In the choice trials, fruits other than avocados had infestations that resulted in adults. The no-choice studies included ‘Hass’ avocados only. In the no-choice studies, no adults developed from oviposited eggs. ARS reviewed the research results and concluded that very poor host status was demonstrated (ARS, 2004; Appendix F).

As further evidence, APHIS analyzed export program data records. Over ten million avocados were cut over the past six years as part of the inspection of imports to the United States; none were found positive for fruit flies. (Table 4). Based on the conclusions provided by Aluja *et al.* (In Press), ARS (2004), and the analysis of the cutting data (Table 4), APHIS concluded that commercially produced ‘Hass’ avocados exported under the systems approach are a very poor host for the *Anastrepha* species tested, as they present a low risk of remaining in the pathway after mitigation.

Anastrepha obliqua and *A. serpentina* were addressed in the non-host research of Aluja *et al.* (In Press a). Neither species has been reliably documented as infesting avocado (Norrbon, In Press; Norrbom and Kim, 1988), therefore they are not listed as being in the pathway.

Anastrepha fraterculus (Mexico population) is not addressed in the research of Aluja *et al.* (In Press a). Genetic and host studies have indicated that cryptic species probably exist within *A. fraterculus* (Selivon and Perondini, 1998; Smith-Caldas *et al.*, 2001). Other studies (Aluja *et al.*, 2003; Baker *et al.*, 1944; Steck, 1991, 1999; Steck & Sheppard, 1993) have indicated that the Mexico population of the complex differs in host usage from the South American populations. South American populations may infest avocado (Norrbon, In Press; Norrbom and Kim, 1988; Ovruski *et al.*, 2003), while the Mexico population does not infest avocado (Aluja *et al.*, 2003, In Press b). Based on the above evidence, APHIS excludes the Mexico populations of the nominate species from the pathway.

Ceratitis capitata can infest avocado (Liquido *et al.*, 1998) and is a quarantine pathway pest. The species was excluded from further consideration because it is under official control and is found only on the Mexico-Guatemala border (APHIS, 1999).

Conotrachelus aguacatae, *C. perseae*, *Heilipus lauri*, *Copturus aguacatae*, and *Stenoma catenifer* are quarantine pests that attack fruit internally; these pests are in the pathway prior to mitigation (Garcia *et al.*, 1998; Wysoki *et al.*, 2002).

The remaining listed arthropod species in Table A-2 do not follow the pathway because they are associated with plant parts other than the mature fruit; these species can only occur in rotting fruit or are mobile and highly likely to be removed during harvest and handling (APHIS, 2000).

The following pests are quarantine pathway pests:

- *Conotrachelus aguacatae* - seed weevil
- *Conotrachelus perseae* - seed weevil
- *Heilipus lauri* - seed weevil
- *Copturus aguacatae* - stem weevil
- *Stenoma catenifer* - seed moth
- *Ceratitis capitata*, *Anastrepha ludens*, *A. striata* - fruit flies

The fruit flies, seed weevils, stem weevil, and seed moth are analyzed quantitatively to determine likelihood of introduction.

Pathway Scenario Model

A quantitative model was developed as a component of our analysis involving the risk of introduction of pathway pests:

seed weevils (*Conotrachelus aguacatae*, *C. perseae*, *H. lauri*), stem weevils (*C. aguacatae*), seed moths (*S. catenifer*), and fruit flies (*Anastrepha* spp., *C. capitata*).

Two quantitative evaluations were performed. The seed moth, stem weevil and three seed weevils are exclusively avocado pests, and are dealt with as one quantitative analysis. The fruit flies have a broader host range, so their risk is addressed in a separate quantitative analysis.

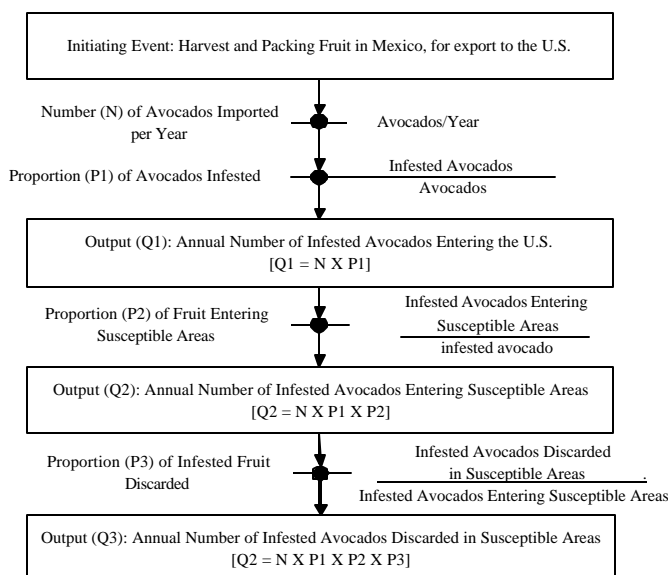


Figure 1. Mexican Hass Avocado Pathway Scenario

The scenario considered is the importation of ‘Hass’ avocados from Michoacán, Mexico and its distribution in the United States year-round. The pathway extends from harvest and packing in Mexico, through all of the mitigations described in the key safeguards section, and terminates with infested avocados distributed to susceptible areas (areas where ecological factors allow establishment of pests) in the United States (Q2, Figure 1). Outputs of this model include estimates for the number of infested avocados that will reach the United States (Q1), the number of avocados that will reach susceptible areas in the United States each year (Q2), and the number of avocados that will be discarded in susceptible areas in the United States each year (Q3). The model assumes compliance with the mitigations in the systems approach (key safeguards section).

N – Annual Number of Fruit Imported

The quantity of Hass avocados that would be imported from Mexico if they were allowed to enter all states during all seasons of the year, is uncertain, so we used ranges that capture our understanding of this value (Figure 2). The estimation of the annual number of fruit imported is based on two import ranges, one nested within the other. The broader range represents amounts that could be imported without reference to market expectations. Hass avocado imports from Mexico in 2002 serve as a lower bound for this range, and potential imports, based on the expected total production in certified orchards after five years, is the upper bound. Within this first range, a second narrower range represents the amount of avocados Mexico’s exporters would expect to send to the United States in the next several years, if shipments to the US were allowed year-round.

The lower bound of the broader range is 27,000 metric tons per year, the quantity of

Hass avocados imported from Mexico in 2002 (U.S. Department of Commerce, Bureau of the Census, 2002). The upper bound of this range is 425,000 metric tons per year. Derivation of this quantity is based on the expected total production in certified areas in 2004: 211,500 metric tons (23,500 hectares and 9 metric tons per hectare). An annual rate of increase in the certified area of 15 percent over five years, based on industry expectations, yields the 425,000 metric tons. This upper bound assumes that all production from all certified orchards would be exported to the United States. It is unlikely that the actual number of avocados imported would exceed this level because the upper bounds (425,402 metric tons) exceeds the U.S. supply of avocados of all varieties from all sources, domestic and foreign, in 2002.

The second, narrower range has lower and upper bounds of 100,000 metric tons and 150,000 metric tons, respectively. The lower bound is based on per capita sales of Mexican Hass avocados in those states where they are currently allowed to be imported, October 15 to April 15, namely, 0.38 pounds per person for the six-month period (Table 4). When this rate of consumption is extrapolated to all states year-round, the total quantity is about 219 million pounds, or roughly 100,000 metric tons per year. The upper bound, 150,000 tons per year, is based on the maximum quantity that the Mexican avocado industry expects to export to the United States for the foreseeable future (APHIS, 2003e). This range is used to estimate the most likely value for the distribution of imports (see Appendix D).

The annual quantity in tons is multiplied by the number of avocados per metric ton (1000 kgs per ton multiplied by 2.2046 lbs per kilogram multiplied by 48 avocados per 25 lbs equals 4233 avocados per metric tons) to yield the annual number of avocados imported annually. The distribution for the annual number of avocados imported is represented in Fig. 2. (For details of derivations see appendix D).

Figure 2

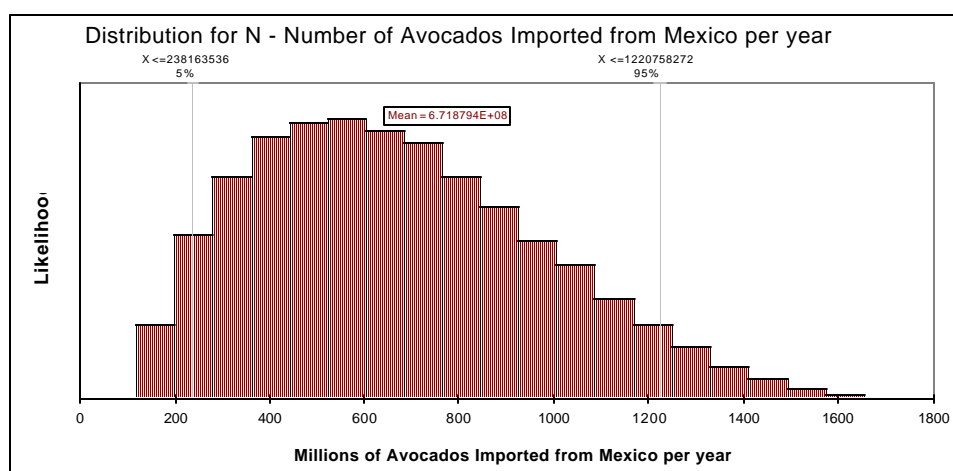


Table 4. Quantity of Hass avocados that would be imported from Mexico, assuming that year-round consumption in all states is equal to the rate of per capita consumption of Hass avocados from Mexico in the Northeast, East Central, and West Central regions, October 15, 2002 - April 15, 2003.

<u>Region¹</u>	<u>2002 Population</u>	<u>Hass avocado imports from Mexico, Oct 15, 2002 to Apr 15, 2003</u>	<u>Per Capita Consumption in the NE, EC, and WC Regions, Oct 15 - Apr 15</u>	<u>Hass Avocado Imports from Mexico, Assuming Average per Capita Consumption Year-round of 0.76 Pound</u>
		pounds	pounds per capita	pounds
North East	70,158,899			
East Central	49,765,488			
West Central	25,383,994			
NE, EC, WC Regions	145,308,381	55,336,757	0.381	
Southeast	58,049,092			
Southwest	27,128,666			
Pacific	57,882,559			
SE, SW, Pacific Regions	143,060,317			
United States	288,368,698			219,160,210

P1 – Proportion of Avocados Infested

Three sources of data relevant to the proportion of avocados infested were identified. First, six years of fruit cutting data for avocados imported to the United States were compiled by APHIS (Table 5). Second, Japan compiled data on avocado inspections for importation from 1992-1994 (Federal Register 60 no. 127: 34835. 1995.) as reported below. Finally, data from foliage surveys for pests in Michoacán orchards between 1997 and 2000 were available (Table 6a and 6b). Only the first source (U.S. fruit cutting data) is used to estimate the proportion of avocados infested. The other two data sources are not used in the quantitative estimation but the results of all three data sources are consistent. The three data sets are presented and discussed below.

Mexican and APHIS Fruit cutting data

Mexican and APHIS officials inspected more than ten million avocados over the past six years and found zero infested avocados (APHIS, 2001a, b; Table 5). The *Work Plan for the Exportation of 'Hass' Avocados from Mexico to the United States of*

Table 5. Fruit sampled and cut for seed weevils, stem weevil, seed moth, and fruit flies*

Season	Field Samples	Packing house	Border Inspection	Row Total	Quarantine Pests
1997/1998	1,155,305	417,900	10,410	1,583,615	None
1998/1999	1,121,471	203,250	16,860	1,341,581	None
1999/2000	952,423	166,650	20,070	1,139,143	None
2000/2001	1,209,814	172,800	17,280	1,399,894	None
2001/2002	1,616,456	347,475	41,250	2,005,181	None
2002/2003	2,749,876	141,558	11,880	2,903,314	None
Subtotal	8,805,345	1,449,633	117,750	10,372,728	None
*Source: Federal Register Vol. 66, No. 135, p 36896-7 and Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion, Mexico. The table was updated with information from the 2001/2002 and 2002/2003 shipping seasons (APHIS, 2003b).					

America (USDA, 2001b - Appendix E) details the procedures for avocado inspections. The inspectors cut the fruit, including the seed, into multiple thin slices that are visually examined for fruit flies, seed pests, and stem weevils. Fruits are inspected in the orchards during harvest, in the packinghouses in Mexico, and on arrival in the United States. Seventy-five fruit are sampled from each field truck arriving at the packinghouse from the orchard. That level of sampling is equivalent to sampling 300 fruit per shipment departing the packinghouse. DHS inspectors examine one avocado from each of 30 boxes on each truck arriving at ports of entry.

The sensitivity of avocado inspection is estimated to be 50%, meaning that an inspector would find 50% of the infested, sampled avocados. This estimate is based on research by Gould (1995) who reported that the sensitivity of inspections for Caribbean fruit fly larvae in grapefruit was 35% and the sensitivity for starfruit inspections was 80%. The ability to detect a pest is greater for fruit with uniform, smooth pulp. Avocados have uniform, smooth pulp and inspectors can easily find blemishes, pest tunnels, and larvae. The estimate of 50% is slightly less than the average sensitivity reported for starfruit and grapefruit ($[35\% + 80\%] \div 2 = 57.5\%$).

The sensitivity of avocado inspection may vary somewhat among pathway pests. All of them can damage the fruit pulp when present in the fruit; however, the stem weevil (*Copturus aguacatae*) produces tunnels that are usually restricted to a small portion of the fruit close to the peduncle. Stem weevil larvae rarely migrate into the fruit, but when they do, they are usually localized to the area of the fruit near the peduncle (Gudino Juarez and Garcia Guzman, 1990). Stem weevil infestation can best be detected by examining the small branches in the orchard. APHIS has determined that 50% is a reasonable estimate of fruit inspection sensitivity for stem weevils that may be in the fruit.

Japanese fruit cutting data

From 1992 to 1994 Mexico shipped 5,230,114 kg of ‘Hass’ avocados to Japan (about 14 million fruit). Japanese agricultural officials inspected 16,000 kg (or about 50,000 of fruits); no target pests of concern to the US were reported, which is (Federal Register 60 no. 127: 34835. 1995.) consistent with the results from the other two sources.

Mexico fruit cutting data

From July 1992 to May 1994, Martinez *et al.* (1993) sampled and cut 153,500 kg of fruit (618,975 fruits) from packinghouses representing 257 orchards and four municipalities (Uruapan, Salvador Escalante, Tancitaro and Periban); there were no reports of fruit flies found. A report from Enkerlin *et al.* (1994 unpublished) tells that 2,300 kg of fruit was cut (12,683 fruits) from an orchard in Uruapan from November 1993 to April 1994, and no fruit flies were found.

Foliage survey data

Data from orchard surveys conducted by Mexico and APHIS is indirect evidence of the proportion of avocados infested (Tables 6a and 6b).

**Table 6a - Foliage Surveys in Avocado Orchards in Michoacán, Mexico
(In orchards that applied for inclusion in the export program)**

Year	Number of Orchards	Number of Orchards Positive				
		Stem Weevil <i>Copturus aguacatae</i>	Seed Weevil <i>Heilipus lauri</i>	Seed Moth <i>Stenoma catenifer</i>	Seed Weevil <i>Conotrachelus aguacatae</i>	Seed Weevil <i>Conotrachelus perseae</i>
1997	61	0	0	0	0	0
1998	244	0	0	0	0	0
1999	500	3	0	0	0	0
2000	790	0	0	0	0	0
2001	996	1	0	0	0	0
2002	1,469	3	0	0	0	0
Total	4,060	7	0	0	0	0

Table 6b – Wild and Backyard Tree Surveys in Michoacán, Mexico

Year	No. of backyards	No. of wild trees surveyed	Number of Sites Positive				
			Stem Weevil <i>Copturus aguacatae</i>	Seed Weevil <i>Heilipus lauri</i>	Seed Moth <i>Stenoma catenifer</i>	Seed Weevil <i>Conotrachelus aguacatae</i>	Seed Weevil <i>Conotrachelus perseae</i>
1997	42	200	0	0	0	0	0
1998		107	19	0	0	0	0
1999	31	379	37	0	0	0	0
2000	54	270	25	0	0	0	0
2001	54	191	24	0	0	0	0
2002	398	762	145	0	0	0	0
Total	661	1,909	250	0	0	0	0

Source - APHIS International Services. – NAR, 2003- Uruapan, Michoacán.

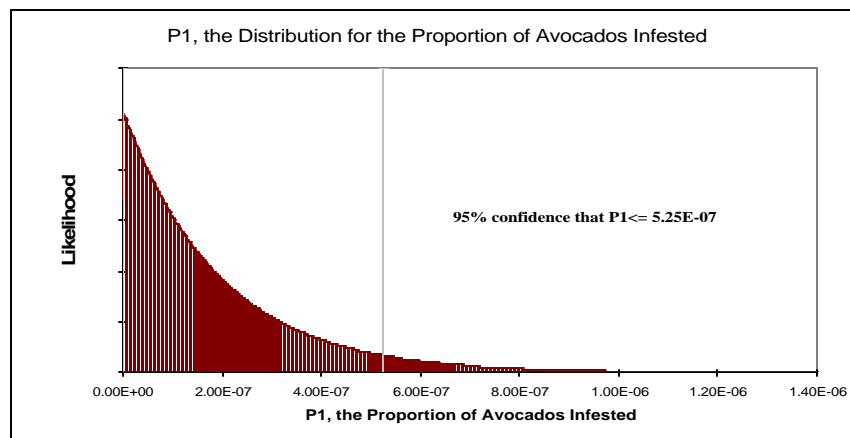
The current avocado rule requires annual surveillance of municipalities approved to export avocados to the United States for four pathway pests (*H. lauri*, *S. catenifer*, *C. aguacatae*, and *C. perseae*). These four pests, controlled at the level of the municipality, were never found in the six annual surveys of the municipalities in Michoacán (Table 6a and 6b). *Copturus aguacatae* was frequently found in orchards and other sites during surveys in Michoacán (Table 6a and 6b); however, this pest was rarely found in surveys of orchards registered to export to the United States, and never found in dissected fruit for export. In annual inspections, seven orchards were positive over the six years that the surveys were conducted. Data from surveys of municipalities and orchards were not used in estimating P1 (the proportion of fruit infested) because the data is an indirect measure of fruit infestation prevalence; however, orchard infestation is a necessary prerequisite for fruit infestation. The orchard survey corroborates the fruit cutting results (Table 5). Additionally, although adult fruit flies (*Anastrepha* spp.) have been frequently trapped in all of the participating municipalities over the last six years (Aluja *et al.*, In Press a; APHIS, 2003a), no larvae have been reported in cut fruit (Table 5).

In estimating the proportion of avocados infested, the sampling distribution surfaces from a binomial process. The implicit assumptions are that: (a) avocados are either infested or not infested; (b) infested avocados are randomly distributed throughout shipments; and (c) sampling of avocados is random. In reality, infested avocados are probably clustered because fruit from an infested orchard would likely be together in a shipment. Also, sampling in orchards is not random because fallen avocados are targeted for inspection. These potential biases are acknowledged; however, they increase the likelihood of pest detection.

Based on the data, the most likely proportion of infested ‘Hass’ avocados imported annually is zero; the 95% confidence interval ranges from 0 to 5.2×10^{-7} (Table 8 and Figure 3) (For calculations please see Appendix D).

Of the three sources of data discussed (*i.e.*, surveys, Japanese inspection results, and Mexico-APHIS fruit cutting results), only the Mexico-APHIS fruit cutting data were used to determine the proportion of avocados infested. The foliage survey data and Japanese fruit cutting data support the conclusion that the

Figure 3 Probability Distribution for P1, the Proportion of Infested Avocados



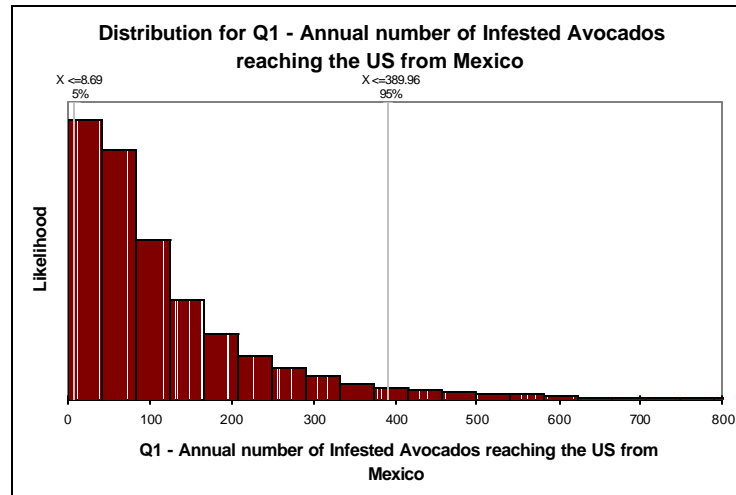
most likely level of infestation is zero.

Q1 – Annual number of infested avocados reaching the United States

The estimate for the annual number of infested avocados that reach the United States (Q1) is the product of the number of avocados imported (N) and the proportion infested (P1) or $Q1 = N \times P1$ (Fig. 4). This estimate includes avocados reaching all areas, not just locations where suitable hosts occur.

Figure 4

Monte Carlo simulation of the model using @Risk (Palisade Corporation, Newfield, New York) and Excel (Microsoft Corporation, Redmond, Washington) resulted in a distribution for Q1 (Figure 4). The most likely value for Q1 is zero; the distribution indicates 95% confidence that the annual number of infested avocados entering the United States is less than 387 avocados (Figure 4 and Table 8).



P2 – Proportion of fruit that will enter susceptible areas in the United States:

Two quantitative determinations were performed for P2 as follows:

1. **For the Avocado Pests** (seed moth, stem weevil and three seed weevils), the susceptible areas are those in which the avocado host exists (avocado growing areas).
2. **For Fruit Flies**, because fruit flies have a broad host range, the area susceptible to fruit fly infestation is the whole of plant hardiness zones 9-11.

Fruit flies

The *fruit fly susceptible area* is all of plant hardiness zones 9-11 in the U.S. Hardiness zones 9-11 includes portions of California, Arizona, Florida, Louisiana, Nevada, Oregon, and Texas plus all of Hawaii. The proportion of avocados entering fruit fly susceptible areas, P2, is represented in the model as a point estimate, and has been determined to be 36.4%.

Other pathway pests

Avocados are the only host in the United States for five pathway pests (*Copturus aguacatae*, *Conotrachelas aguacatae*, *Conotrachelas perseae*, *Heilipus lauri*, and *Stenoma catenifer*). The adult stages of these pests are capable of flight, but do not travel long distances in search of host material; therefore, the geographic area in the United States susceptible by the multiplication and establishment of pathway pests is the region in and around avocado trees. This susceptible area is where pests could find host material and multiply. Exposure of the susceptible area to pathway pests is

estimated by the proportion of avocados consumed in that area.

The proportion of avocados consumed in susceptible areas (P2) is represented in the model as a distribution defined by minimum, most-likely, and maximum values. The minimum susceptible area is the total area of commercial avocado orchards in the U.S. The most likely susceptible area is the total area of commercial avocado orchards in the United States, plus a one-mile buffer zone around each orchard. The maximum susceptible area is all counties in plant hardiness zones 9-11 (see discussion below). The number of avocados consumed in the susceptible area is calculated from the population, which is multiplied by the per capita avocado consumption in the area. The proportion of all avocados consumed in susceptible areas in Table 6 is calculated from the number of avocados consumed in susceptible areas divided by the number of avocados consumed in the United States. Details of the calculations can be found in Appendix D.

The primary source of uncertainty in the estimate of P2 is the area within the United States that is susceptible to the establishment of pathway pests. Backyard and ornamental avocado trees contribute to the susceptible area, but their numbers and locations are unknown. Because of the lack of information on backyard and

ornamental avocado trees, we assume the maximum susceptible area encompasses plant hardiness zones 9-11. This approach is consistent with the principle that less knowledge is modeled by greater uncertainty.

Table 7. Avocados consumed in susceptible areas

	Number consumed	Proportion
Minimum	426,388	0.0006
Most-likely	53,637,359	0.076
Maximum	256,449,505	0.364

The proportion of is avocados consumed in susceptible areas divided by all avocados consumed in the U.S. (703,906,532)

Two assumptions were made in the estimation of P2. We assumed people are evenly distributed throughout the county and that imported avocados are evenly distributed within regions according to the regional per capita consumption rate. These assumptions probably resulted in over-estimation of P2 because of cities located in the area. More Mexican avocados will probably be sent to areas of the country without domestic production, which would reduce the true value of P2 relative to the estimated range. Despite these sources of bias, the wide range of the P2 estimate (0.0006 – 0.375) provides a high level of confidence that the true value occurs within the range.

Q2 – Annual number of infested avocados that enter susceptible regions of the United States

The estimate of Q2 is a product of the number of avocados imported (N), the proportion infested (P1), and the proportion of susceptible counties in the United States (P2) or $Q2 = N \times P1 \times P2$.

Monte Carlo simulation of the model using @Risk[®] resulted in a distribution for Q2 (Figure 5 and 6). The model gives a 95% confidence that no more than 143 fruit fly infested fruit will enter hardiness zone 9-11 each year (fig 6).

The model gives a 95% confidence that no more than 49 fruit infested with seed weevils, (*Conotrachelus aguacatae*, *C. perseae*, *H. lauri*) stem weevils, (*C. aguacatae*) or seed moths (*S. catenifer*) will enter avocado growing areas in the US each year (fig 5).

Q3 – Annual number of infested avocados discarded in susceptible regions of the United States

The estimate of Q3 is a product of the number of avocados imported (N), the proportion infested (P1), the proportion of susceptible counties in the United States (P2), and the proportion of avocados discarded (P3) or $Q3 = N \times P1 \times P2 \times P3$.

Monte Carlo simulation of the model using @Risk[®] resulted in a distribution for Q3 (Figure 7 and 8). The model gives a 95% confidence that no more than 8 fruit fly infested fruit will be discarded in hardiness zone 9-11 each year.

The model gives a 95% confidence that no more than 3 fruit infested with seed weevils, (*Conotrachelus aguacatae*, *C. perseae*, *H. lauri*) stem weevils, (*C. aguacatae*) or seed moths (*S. catenifer*) will be discarded in avocado growing areas in the US each year.

Table 8 - The 95% Confidence Level for Results of the Pathway Model

	Description of Parameter	Fruit Fly Infested	Arthropod Pest Infested
P1	Proportion of Mexican avocados that are infested with a pathway arthropod pest	0.52/1,000,000	0.52/1,000,000
P2	Proportion of infested avocados that enter susceptible areas in the United States	24/100	36.4/100
P3	Proportion of infested avocados that are discarded	5%	5%
Q1	Annual number of infested avocados that enter the United States	387	387
Q2	Annual number of infested avocados that enter susceptible areas in the United States	143	49
Q3	Annual number of infested avocados that are discarded in susceptible areas in the United States	8	3

The results of the quantitative analysis (summarized in Table 8) do not equate to "likelihood of introduction". That is, they express simply how likely it is for an infested avocado to be discarded into a suitable location. However, even if 387 infested avocados entered a suitable location, the likelihood of introduction (establishment and spread) would require additional steps given what we know of pest epidemiology. These additional requirements include: a) the pests survive during transportation and storage, b) the infested avocados must be discarded in close proximity to host material (Table 8 and Appendix D), c) the pests must find mates, d) the pests must successfully avoid predation, e) the adult pests must find host material, f) the climatological and microenvironmental conditions must be suitable, and g) they must escape detection and subsequent eradication measures. The likelihood of establishment is substantially

reduced by the above factors. People generally consume the fruit they purchase and dispose the waste material in a manner (in plastic bags that are placed in trashcans, which are ultimately either landfilled or incinerated) that precludes the release of pests into the environment. For these reasons, our final expression of a likelihood of introduction is a descriptive statement. It is APHIS' finding that the likelihood of introduction of infested avocados through the commercial pathway of Hass avocados imported from Mexico from the state of Michoacan and produced using a systems approach as described here, is low.

Figure 5

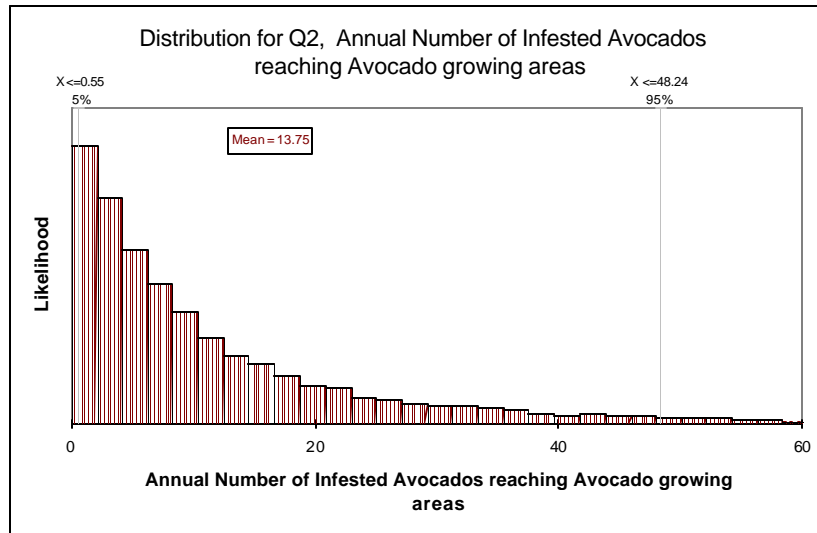


Figure 6

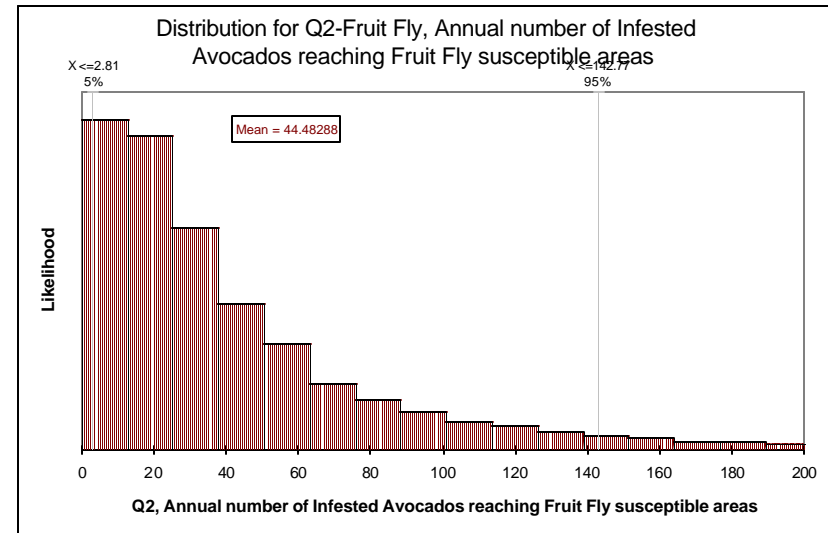


Figure 7

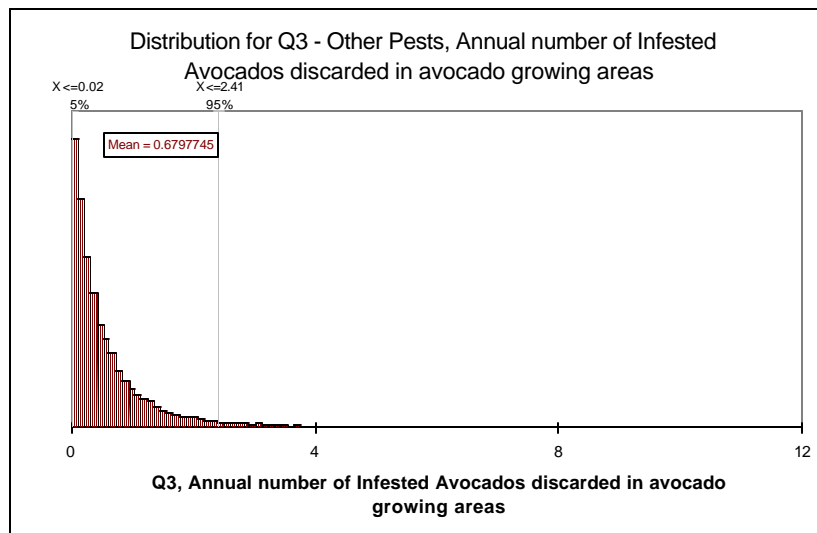
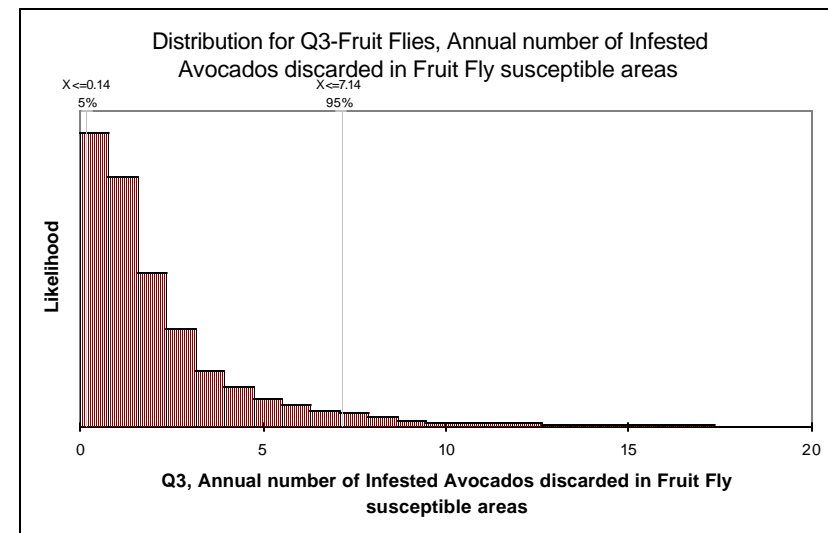


Figure 8



Estimates of Consequences of Introduction

We rated the potential consequences for each pest with respect to five different elements that follow current APHIS (2000) guidelines for commodity risk assessment. The ranking considers pest potential in the absence of specific risk mitigation activities. Criteria for estimating consequences were qualitative. Numerical values (high (3 points), medium (2 points), or low (1 point)) were assigned to each element to assist in categorization. The sum of the five individual ratings provided an estimate of the potential consequences for each pest.

APHIS estimated consequences of introduction for each of the pest categories listed in the previous section as candidates for further analysis. Low impact pests have values of 5-8, medium impact pests have values of 9-12, and high impact pests have values of 13-15.

Risk Element 1: Climate/Host Interaction

When a pest is introduced to a new area it can be expected to behave as it does in its native area if host plants are available and climatic conditions are similar. The evaluation considers ecological zones and the interaction between the geographic distribution of the pest and the host. For this element, risk values are based on the availability of both host material and suitable climate conditions. To rate this risk element, we use the United States Plant Hardiness Zones (Cathey, 1990). Risk values are assigned according to the following: the availability of suitable host plants and suitable climate and the pest's potential to establish a breeding colony:

- High (3): In four or more plant hardiness zones.
- Medium (2): In two or three plant hardiness zones.
- Low (1): In only a single plant hardiness zone.

Risk Element 2: Host range

The risk posed by a plant pest depends on its ability to establish a viable reproductive population and its potential for causing plant damage. We assumed risk is correlated positively with host range. For pathogens, risk is more complex and depends on host range, aggressiveness, virulence and pathogenicity. APHIS rated risk primarily as a function of host range:

- High (3): Pest attacks multiple species within multiple plant families.
- Medium (2): Pest attacks multiple species within a single plant family.
- Low (1): Pest attacks a single species/multiple

Risk Element 3: Dispersal Potential

A pest may disperse after establishment in a new area. Consider the following:

- reproductive patterns in the pest (*e.g.*, voltinism, reproductive output)
- innate dispersal capability of the pest
- natural factors (*e.g.*, wind, water, presence of vectors) facilitate dispersal

High (3): Pest has high reproductive potential (*e.g.*, multiple generations or cohorts per year, many offspring per reproductive event, high capacity of a population for increase), *AND* individuals are highly mobile (*i.e.*, capable of moving long distances, over 10 km/year, either under their own power, or by being moved by natural forces such as wind, water or vectors).

Medium (2): Pest has either high reproductive potential *OR* the species is mobile.

Low (1): Neither high reproductive potential nor highly mobile.

Risk Element 4: Economic Impact

Introduced pests are capable of causing a variety of economic impacts. We divide these impacts into three categories: 1. Lower yield of the host crop (*e.g.*, by causing plant mortality, or by acting as a disease vector); 2. Lower value of the commodity (*e.g.*, by increasing costs of production, lowering market price, or a combination); 3. Loss of markets (foreign or domestic).

High (3): Pest causes all three types of impacts.

Medium (2): Pest causes any two of the above impacts.

Low (1): Pest causes any one of the above impacts.

Risk Element 5: Environmental Impact

The analysis considered the following four elements:

1. Establishment of the pest is expected to cause significant, direct environmental impacts (*e.g.*, ecological disruptions, reduced biodiversity).
2. Pest is expected to have direct impacts on the species listed by Federal or State agencies as endangered, threatened, or a candidate. An example of a direct impact would be feeding on a listed plant. If feeding trials with the pest have not been conducted on the listed organism (no direct negative data), a pest will be expected to feed on the plant if it feeds on other species within the genus or other genera within the family.
3. Pest is expected to have indirect impacts on the species listed by Federal or State agencies as endangered, threatened, or candidate species (*e.g.*, by disrupting sensitive, critical habitat).
4. Establishment of the pest would stimulate control programs consisting of toxic chemical pesticides, or release of non-indigenous biological control agents.

High (3): Two or more of the above.
Medium (2) One of the above.
Low (1): None of the above (it is assumed that establishment of a non-indigenous pest will usually have an environmental impact).

Seed weevils (*Conotrachelas aguacatae*, *C. perseae*, *Heilipus lauri*)

Climate/host interaction—Seed weevils infest avocado only (CPC, 2001), which has tropical or subtropical distribution in hardiness zones 9-11 in Central America (Whitehead, 1979a). Avocado has the same climatic distribution in California, Florida and Hawaii (NASS, 1997) This factor is rated medium (2).

Host range—Seed weevils species infest avocado only, (this includes all varieties) (CPC, 2001), thus the rating is low (1).

Dispersal potential— Seed weevils have long life cycles (60-180 days), 2-3 generations per year, and adults are long-lived (about 90-120 days). Females of *Conotrachelus* spp. can lay up to 70 eggs and *H. lauri* may lay up to 144 eggs. Immature stages may remain up to 90 days in fruit. Adults are sedentary and tend to remain in the foliage of the host tree, but are capable of flying between orchards (CPC, 2001; Garcia *et al.*, 1998; Teliz, 2000; Wysoki *et al.*, 2002). Larvae are internal and can be transported worldwide by human. Because of their sedentary nature, APHIS considered seed weevils to have a low rating; however, their long life span increases the likelihood of assisted movement and, therefore, they are given a final ranking of high (3) for this factor.

Economic impact—Seed weevils can cause up to 80% yield loss in the export area (Garcia, *et al.*, 1998; Wysoki *et al.*, 2002). A yield loss of 20% is expected if the pest has an outbreak in the PRA area, after which the annual production costs could increase by 41%, avocado yields could decrease by 20% (due to limited effectiveness of aerial treatments), and estimated social losses could total \$123.6 million per year (Evangelou, *et al.*, 1993). Spray programs for adults are required if they are detected by surveys (Teliz, 2000). The species are regulated pests (APHIS, 2002) and are likely to trigger quarantines of exported avocados from the United States to other countries. This justified a rating of high (3).

Environmental impact— Seed weevils infest only avocado. (There are no associations with endangered or threatened species.) Spray programs could commence in commercial avocado-growing areas if an outbreak occurs (Evangelou, *et al.*, 1993). Increased sprays from eradication programs could increase impacts on endangered or threatened species beyond those impacts already caused by existing agriculture. This factor was thus rated as medium (2).

The overall cumulative risk rating for the consequences of introduction for seed weevils was considered medium (11). Generally, medium risk reflects evidence that the three species are monophagous and would, at most, be narrowly distributed with

one host in the PRA area, if they should become introduced and established.

Stem weevil

Climate/host interaction The stem weevil infests only avocado, which has tropical or subtropical distribution in hardiness zones 9-11 in Mexico (Velez, 1959). Avocados have the same climatic distribution in the United States. This factor is rated medium (2).

Host range—Avocado (including all varieties) is the only host for the stem weevil (Velez, 1959). This factor was rated low (1).

Dispersal potential—The life cycle of the stem weevil is long (>150 days) with a protracted larval stage (>115 days), which, in turn, limits the number of 1-2 generations annually (Teliz, 2000). Females only lay up to eight eggs (Velez, 1959). Adults are capable of short flights, but typically remain in foliage (Garcia, *et al.*, 1998) within an orchard. Larvae are internal and the main method of spread is by human. Because of their sedentary nature, we considered the stem weevil to have a low rating. Their long life span increases the likelihood of movement and that was the reasoning for a ranking of medium (2).

Economic impact—Sprays are recommended in the export country when the stem weevil is detected (Teliz, 2000). A yield loss of 20% is expected if the pest has an outbreak in the PRA area, annual production costs could increase by 41%, avocado yields could decrease by 20% (due to limited effectiveness of aerial treatments), and estimated social losses could total \$123.6 million per year (Evangelou, *et al.*, 1993). The species is a regulated pest (APHIS, 2002) and is likely to trigger quarantines of avocados exported from the US to other countries. This justified a rating of high (3).

Environmental impact—Stem weevils infest only avocado and there are no associations with endangered or threatened species. Spray programs will commence in commercial avocado-growing areas of the PRA area if an outbreak should occur (Evangelou, *et al.*, 1993). Increased sprays from eradication programs could increase impacts on endangered or threatened species beyond those impacts already caused by existing agriculture. This factor was rated as medium (2).

The overall impact potential for stem weevils is medium (10).

Seed moth

Climate/host interaction—The seed moth infests avocado and related species, which have tropical or subtropical distribution in hardiness zones 9-11 in Central and South America (Cervantes-Peredo, *et al.*, 1999). Avocados have the same climatic distribution in the United States (National Agric. Statistics Service, <http://www.usda.gov/nass/>). The seed moth may be able to infest *Persea borbonia* (L.) Spreng. (redbay) because avocados and redbay belong to the same genus.; however, redbay is not a reported host for the seed moth. Redbay occurs along the south Atlantic and Gulf coasts (USFS, 2002). The two hosts overlap in hardiness

zones 7-9. This factor is rated medium (2).

Host range—The seed moth infests species in several genera of Lauraceae, including greenheart, *Chlorocardium rodiei* (Schomb.) Rohwer Richter & van der Werff (Cervantes-Peredo, *et al.*, 1999). All avocados, of all varieties, are the only known host in the United States for the seed moth. This factor was rated low (1).

Dispersal potential—The seed moth occurs widely over Mexico, but is limited there to avocados grown below 1,000 m in elevation and, apparently, does not occur in the export program area (Cervantes-Peredo, 2000). Adults can fly and females have high reproductive potential; they can lay up to 240 eggs at one time (Jaramillo *et al.*, 1972). Up to three generations per year are recorded (Garcia, *et al.*, 1998). Because larvae are internal, worldwide spread by human is possible. This factor was rated high (3).

Economic impact—Fruits of all sizes are infested by seed moth. Fruits that are infested when small fall off the tree before reaching harvestable size (Cervantes-Peredo, 2000). Over 80% of avocados (not 'Hass' variety) in some Brazilian orchards were infested, and over 80% of those fell before reaching their harvestable size (Ventura, *et al.*, 1999). In field reports from South America, it was noted that 'Hass' avocados were not infested, but more than 54% of other avocado cultivars received damage (Arellano-Cruz, 1998). The seed moth is a regulated pest (APHIS, 2002) and it is likely that other countries would quarantine this pest if it were to become established. This factor was rated high (3).

Environmental impact—If an outbreak of the seed moth should occur in United States' avocado orchards, spray programs against adults, like those described for seed and stem weevils (Evangelou, *et al.*, 1993), would begin in commercial avocado growing areas. Increased spraying from eradication programs could increase the impact on endangered or threatened species. This factor was rated as medium (2).

Following the guidelines, the overall impact potential for the seed moth was considered medium (11).

Fruit flies (*Anastrepha ludens*, *A. striata*, *Ceratitis capitata*)

Avocados are not considered a reliably documented host for *Anastrepha serpentina*, *A. fraterculus* (Mexico populations) or *A. obliqua* (Norrbon, In Press).

Climate/host interaction— These fruit flies infest many hosts over a range that includes tropical and subtropical areas. *Anastrepha striata* occurs from Mexico to Brazil and outbreaks have occurred in Texas and California; therefore, it may be expected to inhabit hardiness zones 8-11. *Anastrepha ludens* occurs from northern Mexico to Costa Rica, and outbreaks have occurred in Texas and California; therefore, it may be expected to occur over hardiness zones 8-11 (Foote *et al.*, 1993; Sequeira *et al.*, 2001). *Ceratitis capitata* occurs over southern Europe and throughout Central and South America (CPC, 2002), it is established in Hawaii, and outbreaks have occurred in Florida and California; therefore, it may be expected to inhabit hardiness zones 8-11 (APHIS, 1999; USDA, 2001a). This factor is rated high (3) for these species.

Host range—*Anastrepha striata* infests *Prunus persica*, *Persea*, *Eugenia*, *Mangifera*, *Passiflora*, *Diospyros*, *Manihot*, and other genera in multiple families. *Anastrepha ludens* infests *Prunus persica*, *Annona*, *Casimiroa*, *Citrus*, *Cydonia*, *Mammea*, *Mangifera*, *Persea*, *Psidium*, *Pyrus* and other genera representing over five families (Norrbon, In Press). *Ceratitis capitata* infests over 100 crop and non-crop species, including *Opuntia*, *Persea*, *Prunus*, *Malus*, *Capsicum*, and others in over 10 families (Liquido *et al.*, 1998). This factor is rated high for all species (3).

Dispersal potential—All of these fruit flies have been documented to have continuous generations within their ranges, females live several months and are capable of laying over 100 eggs each. The fruit fly's life cycle is less than 45 days, under optimum conditions, capability to spread naturally by flight over 20 km per year, and capability to spread worldwide in commerce (CPC, 2002; Fletcher, 1989; Foote *et al.*, 1993; Liquido *et al.*, 1998; Norrbom, In Press; Sequeira *et al.*, 2001; White and Elson-Harris, 1994). This factor is rated high for all species (3).

Economic impact—All of these species are regulated pests (APHIS, 2002); as a result, their establishment in the United States could trigger quarantines against exports. *Anastrepha striata* is the primary pest of guava in Venezuela, reducing both the yield and quality of fruit (Marin Acosta, 1973). *Anastrepha ludens* infestations in citrus could cause a decrease in yield and quality in the United States valued at \$70 million (1975 prices) (Andrew *et al.*, 1977; Erikson *et al.*, 2000). *Ceratitis capitata* infestation may cause high yield and quality losses requiring up to \$341 million in additional production costs if it should become established in California (CDFA, 2003). This factor is rated high for all species (3).

Environmental impact—If an outbreak was detected, all species would be expected to trigger APHIS eradication programs involving area-wide spray programs that could cause ecological destruction; these programs have been previously used Florida, Texas, and California (Sequeira *et al.*, 2001). *Anastrepha striata* may infest the listed species of *Eugenia* and *Prunus*. *A. ludens* may infest the listed species of *Prunus*. *Ceratitis capitata* may infest listed species of *Opuntia* and *Prunus* (USFWS, 2002). This factor is rated high for all species (3).

Following the guidelines, the overall consequences potential for the fruit flies is high (15).

The scores for each of the elements, as related to the pest in question, are presented in Table 7. The potential consequences associated with each pest are estimated by adding together the values (one for each element).

Table 9 - Summary of potential consequences from quarantine pathway pests						
Pest	Climate/Host Interaction	Host range	Dispersal Potential	Economic Impact	Environmental Impact	Total
Seed weevils	2 Medium	1 Low	3 High	3 High	2 Medium	11 Medium
Stem weevil	2 Medium	1 Low	2 Medium	3 High	2 Medium	10 Medium
Seed moth	2 Medium	1 Low	3 High	3 High	2 Medium	11 Medium
Fruit flies	3 High	3 High	3 High	3 High	3 High	15 High
Note: Descriptions of elements and assignment of values are explained in the text. This ranking did not consider specific mitigation practices (APHIS, 2000).						

Discussion

The most likely annual number of avocados infested with a pathway pest that is likely to be imported from Mexico each year under the expanded distribution scenario and proposed systems approach is zero. Based on the fruit cutting data alone (ignoring the results of the area and orchard surveys and the risk-reducing effects of every element in the systems approach), the quantitative model indicates a 95% level of confidence that the annual number of infested avocados likely to enter the United States is not more than 387; furthermore, the number likely to enter avocado growing areas in the United States is not more than 49 for seed weevils, stem borers and seed moth, and 143 for fruit flies to fruit fly susceptible areas. Of the above numbers, only 8 fruits infested with fruit flies or 3 fruits infested with seed weevils, stem borer and seed moth would be expected to be discarded in susceptible areas (Table 8).

Even if 387 infested avocados entered the country, the likelihood of pest establishment and spread would require that a) the pests survive during transportation and storage, b) the infested avocados must be discarded in close proximity to host material (Table 8 and Appendix D), c) the pests must find mates, d) the pests must successfully avoid predation, e) the adult pests must find host material, f) the climatological and microenvironmental conditions must be suitable, and g) they must escape detection and subsequent eradication measures. The likelihood of establishment is substantially reduced by the above factors. The degree of pest reduction attributable to each of the factors has not been quantified. People generally consume the fruit they purchase and dispose the waste material in a manner (in plastic bags that are placed in trashcans, which are ultimately either landfilled or incinerated) that precludes the release of pests into the environment.

If an outbreak of a regulated quarantine pest occurs, APHIS may implement emergency domestic eradication programs as it has for fruit flies and other pests in the recent past. It is probable that the programs will involve pesticide applications. Pesticides appropriate for control of the particular pest and approved for emergency use by EPA will be used. The pesticides used would be those normally used to control pests in regular pest management systems in the United States.

The rate of avocado pests that would enter the United States in commercial avocados legally imported and in compliance with the proposed modified systems approach is certainly far lower than the rate of prohibited avocados in passenger baggage and other types of cargo. Port of entry interception database records indicate that pathway pests are routinely found in avocados (both 'Hass' and other varieties) intercepted at United States ports of entry.

The rate of avocado pests entering the United States in legally imported commercial fruit, if these pests are entering at all, is a most likely value of zero; this rate of pests entering is far lower than the rate of prohibited avocados arriving at U.S. ports of entry in the baggage of travelers. APHIS-PPQ data (APHIS, 2003c) indicate that pathway

pests are routinely found in prohibited avocados intercepted in baggage and cargo at U.S. ports of entry. During the seventeen-year period from 1985 to 2002, an average of 30 avocados infested with pathway pests were intercepted and denied entry into the United States each year. Studies of port efficiency (Miller *et al.*, 1996; Meissner *et al.*, 2003), when searching for prohibited materials, recommends that inspectors detect approximately 10-20% of what actually arrives. That suggests that an estimated average 150 to 300 infested avocados are introduced each year through baggage and cargo. During the period 1985 to 2002, 502 pathway pests were detected in intercepted avocados (specific variety or cultivar not recorded) that were found in baggage and cargo: *Conotrachelus* sp.: 242; *Copturus* sp.: 5; *Heilipus* sp.: 38; *Stenomoma* sp.: 217. During the same period, 24,283 tephritid larvae were intercepted at the Mexico border in all types of fruit, most of it from baggage (APHIS, 2004). Prohibited avocados in baggage and cargo pose a substantially greater risk to U.S. agriculture than commercial imports of 'Hass' avocados from Mexico. Legalizing imports of avocados from Mexico could reduce smuggling of the commodity into the United States.

In addition to the presence of fruit flies in prohibited baggage, another background occurrence of *Anastrepha ludens* is recorded to occur in southern Texas for the past decade. Thousands of fruit flies are trapped yearly in this area and are currently under an eradication program (Dave Bartels, personal communication 2003); however, there has been no establishment of *A. ludens* beyond southern Texas to other growing regions in the United States. At this time (2004), *A. ludens* is still in southern Texas. This evidence suggests that spread of *A. ludens* to northern production areas is unlikely.

APHIS concluded that prohibited avocados in baggage and cargo pose a greater risk to United States agriculture than commercial imports of 'Hass' avocados from Mexico. The continued occurrence of *A. ludens* in southern Texas over the past ten or more years further supports the conclusion that background exposure is greater than that associated with commercial importation of 'Hass' avocados.

Conclusions

1. Avocados from Mexico are a potential pathway for the following quarantine pests: three fruit flies: *Anastrepha ludens*, *A. striata*, and *Ceratitis capitata*; three seed weevils: *Conotrachelus aguacatae*, *C. perseae*, and *Heilipus lauri*; one stem weevil: *Copturus aguacatae*; and one seed moth: *Stenomoma catenifer*.
2. Repeated area surveys and inspections of orchards and processed fruit by Mexican and USDA-APHIS personnel for over six years have failed to find *Conotrachelus aguacatae*, *Heilipus lauri*, and *Stenomoma catenifer* and *Conotrachelus perseae*. Over ten million fruit have been examined for pest larva with negative results.

The stem weevil, *Copturus aguacatae*, is known to exist in Michoacán. The pest was

detected seven times in annual surveys of export-eligible orchards over six years. Those orchards were subsequently prohibited to export fruit. The pest was never found in exported fruit.

Fruit fly adults are regularly trapped, and will continue to be monitored, in exporting orchards. The orchards are subject to mandatory controls and bait spraying when fruit flies are detected, but no larvae have been detected by fruit cutting. Experiments (Aluja *et al.*, In Press a) and ARS (2004, Appendix F) conclusions on fruit flies have led APHIS to conclude that *Anastrepha* spp. are of low likelihood to be in the pathway of entry in commercial 'Hass' avocado fruit. *Ceratitis capitata* is of low likelihood to be in the pathway because it is officially controlled in Mexico and does not occur in Michoacán.

3. The systems approach is effective. Six years experience, including the dissection of over ten million fruit, validates the effectiveness of the systems approach in preventing the introduction of Mexican avocado pests. The systems approach for avocado imports focuses on preventing infestation and detecting infection, if it occurs. The systems approach includes redundant safeguards, such as surveys, orchard inspections, orchard treatments, certification, fruit inspection, and trace-back ability.

4. The number of avocados that have been inspected over the last six years allows estimation of the highest number of infested avocados that could be imported without detection with a high degree of precision. Specifically, the most likely proportion of infested avocados annually imported was found to be zero; the 95% confidence interval ranged from 0 to 5.25×10^{-7} [that is, from 0 to 52.5/100,000,000]. The above pertains to fruit flies, seed weevils, stem weevil, and seed moth.

5. A probabilistic analysis, based on the fruit cutting data and forecast fruit exported to the United States, found that the annual number of imported fruit infested with any pathway pest and distributed to avocado-producing counties per year is most likely zero. APHIS conclusions are based on the fruit cutting data obtained by APHIS and Mexico from October to April over the past six years and reinforced by Aluja *et al.* (In Press a) regarding the fruit cutting data they obtained from August-October, 2001 and April-June, 2002.

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External Review

Over 300 public and stakeholder comments were received June-September, 2003 from avocado growers, United States legislators, USDA-ARS scientists, state extension scientists, consulting risk analysts, trade representatives, representatives of state departments of agriculture, scientists and government representatives from Mexico and other countries. Many of their ideas were incorporated into this PRA.

Appendix A – Pest List

Appendix A: Pest List

Appendix A-1: CMI 2005

Table A-1: Pathogens.					
Scientific Name ¹ and Common Name	Distribution ²	Comment ³	References		
Fungi					
Armillaria mellea (Vahl:Fr.) P. Kumm. Armillaria root rot	MX CA FL OT	a, c	Ploetz, et al., 1994; CMI, 1980a		
Ascochyta sp.	MX	b, y	APHIS, 2004		
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. in Penz. Teleomorph: Glomerella cingulata (Stone.) Spauld. & H. Schrenk Anthracnose	MX CA FL HI TX OT	c, f	Ploetz, et al., 1994		
Diaporthe rudis (Fr:Fr) Nitschke Synonym: Diaporthe medusaea Nitschke Melanose	MX CA FL TX OT	c, f	Kranz, et al., 1977		
Ganoderma lucidum (Curtis:Fr) P. Karst. Wood rot	MX CA FL TX OT	a, f	Morales-Garcia, 1989; Farr, et al., 1989; CMI, 1975		
Lasiodiplodia theobromae (Pat.) Griffon & Maubl. Stem-end rot	MX CA FL OT	c, f	Alfieri, et al., 1984; CMI, 1976		
Phoma sp.	MX	b, y	APHIS, 2004		
Phomopsis sp.	MX	b, y	APHIS, 2004		
Mycosphaerella perseae L.E. Miles Leaf spot	MX FL	a, f	Farr, et al., 1989; Alfieri, et al., 1984		
Phyllachora gratissima Rehm. Tar spot	MX PR USVI	a, d	Cannon, 1996; Cook, 1975; Farr et al., 2003; Garcia E. & Teliz Ortiz, 1984; Hodges, 1969, 2004; Lopez & Garcia, 1995; Menge & Ploetz, 2003; Otero, 1939; Pirone, 1978; Seaver, 1928; Teliz, 2000; Watson, 1971; Weber, 1973		
Phymatotrichopsis omnivora (Duggar) Hennebert Texas foot rot	MX CA TX	a, c, f	Morales-Garcia, 1989		
Phytophthora cinnamomi Rands Phytophthora root rot	MX CA FL TX OT	a, f	Ploetz, et al., 1994; CMI, 1991		
Phytophthora citricola Sawada Black fruit rot	MX CA OT	c, f	Fucikovsky & Luna, 1987; Ploetz, et al., 1994; CMI, 1979		
Phytophthora nicotianae Breda de Haan var. parasitica (Dastur) G.M. Waterhouse Collar rot	MX CA FL OT	c, f	Alfieri, et al., 1984; Farr, et al., 1989; CMI, 1964		
Pseudocercospora purpurea (Cooke) Deighton Synonym: Cercospora purpurea Cooke	MX CA FL	c, f	Fucikovsky & Luna, 1987; Ploetz, et al., 1994		

Appendix A – Pest List

Table A-1: Pathogens.					
Scientific Name ¹ and Common Name	Distribution ²		Comment ³	References	
Cercospora spot, Blotch					
<i>Pythium ultimum</i> Trow Root rot	MX	CA FL HI OT	a, c, f	French, 1989; CMI, 1981b	
<i>Rhizoctonia solani</i> Kühn Root rot	MX TX	CA FL OT	a, c, f	Alfieri, <i>et al.</i> , 1984; Farr, <i>et al.</i> , 1989; French, 1989; CMI, 1974	
<i>Rosellinia bunodes</i> (Berk. & Br.) Sacc. Black (Rosellinia) root rot	MX		a	Ploetz, <i>et al.</i> , 1994; Watson, 1971; CMI, 1985	
<i>Rosellinia necatrix</i> Prill. Anamorph: <i>Dematophora necatrix</i> R. Hartig White root rot	MX	CA OT	a, f	Ploetz, <i>et al.</i> , 1994; CMI, 1987	
<i>Rosellinia pepo</i> Pat. Black root rot	MX		a	Ploetz, <i>et al.</i> , 1994; CMI, 1968	
<i>Sclerotium rolfsii</i> Sacc. Anamorph: <i>Corticium rolfsii</i> Curzi Seedling blight	MX TX	CA FL HI OT	c, f	Alfieri, <i>et al.</i> , 1984; CMI, 1981a	
<i>Sphaceloma perseae</i> Jenkins Scab, Rona	MX TX	CA FL	c, y	APHIS, 2004; Ploetz, <i>et al.</i> , 1994; CMI, 1986a	
<i>Verticillium albo-atrum</i> Reinke & Bert. Verticillium wilt	MX TX	CA FL OT	a, c, f	Ploetz, <i>et al.</i> , 1994; Morales-Garcia, 1989; CMI, 1986b	
<i>Bacteria</i>					
<i>Agrobacterium tumefaciens</i> (Smith & Town.) Conn Crown gall	MX TX	CA FL OT	a, c, f	Bradbury, 1986; CMI, 1980b	
<i>Erwinia carotovora</i> subsp. <i>carotovora</i> (Jones) Bergey <i>et al.</i> Soft rot	MX TX	CA FL HI OT	c, f	Bradbury, 1986	
<i>Erwinia herbicola</i> (Löhnis) Dye	MX TX	CA FL HI OT	f	Bradbury, 1986; Fucikovsky & Luna, 1987	
<i>Pseudomonas syringae</i> pv. <i>syringae</i> van Hall Fruit spot, Blossom blight, Blast	MX TX	CA FL OT	c, f	Bradbury, 1986; CMI, 1988	
<i>Nematodes</i>					
<i>Radopholus similis</i> (Cobb) Thorne	MX TX	CA FL OT	a, d	Anonymous, 1984; APHIS, 2004; Ploetz, <i>et al.</i> , 1994; Anonymous, 1992	
<i>Virus, viroid and viruslike agents</i>					
Avocado sunblotch viroid	MX	CA FL	f	Fucikovsky & Luna, 1987; Ploetz, <i>et al.</i> , 1994	

¹ Scientific names of fungi and bacteria as listed in Ploetz, *et al.*, 1994; Bradbury, 1986; and Farr, *et al.*, 1989.

² Distribution legend: MX = Mexico; CA = California; FL = Florida; HI = Hawaii; PR = Puerto Rico; TX = Texas; USVI = US Virgin Islands; OT = Other, occurs in states other than CA, FL, HI, TX.

Appendix A – Pest List

³ Comments:

- a = Pest associated with plant part other than commodity
- b = Further analysis not possible because species not identified
- c = Listed in catalogue of pest interceptions as non-reportable (APHIS, 2003c)
- d = Listed in catalogue of pest interceptions as reportable (APHIS, 2004)
- f = Pest occurs in the United States and is not currently subject to official restrictions and regulations
(*i.e.*, not listed as reportable or non-reportable, and no official control program)
- y = Multiple APHIS interceptions exist (APHIS, 2003c; APHIS, 2004).

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Abgrallaspis howardi</i> (Cockerell) (Homoptera: Diaspididae)	MX, US	a, c	Teliz, 2000
<i>Abgrallaspis perseus</i> Davidson (Homoptera: Diaspididae)	MX	g, j, z	APHIS, 2004; Davidson, 1964
<i>Abgrallaspis</i> sp. (Homoptera: Diaspididae)	MX	b, g, j, x	APHIS, 2004
<i>Acanthoscelides</i> sp. (Coleoptera: Bruchidae)	MX	a, b	Adame, 1998
<i>Acutaspis albopicta</i> (Cockerell) (Homoptera: Diaspididae)	MX, US	g, j, z	APHIS, 2004; Nakahara, 1982
<i>Acutaspis perseae</i> (Comstock) (Homoptera: Diaspididae)	MX, US	a, j	Ebeling, 1959
<i>Aeolothrips mexicanus</i> Preisner (Thysanoptera: Aeolothripidae)	MX	a	Teliz, 2000
<i>Aetalion quadratum</i> Fowler (Homoptera: Aetalionidae)	MX	a, g	Ebeling, 1959
Agromyzidae (Diptera), Unidentified species	MX	a, b	Hennessey, 2002
<i>Aleurocanthus woglumi</i> Ashby (Homoptera: Aleyrodidae)	MX, US	a, g	Ballou, 1922; PNKTO No.15
<i>Aleurodicus dugesii</i> (Cockerell) (Homoptera: Aleyrodidae)	MX	a, g	Ebeling, 1959
Aleyrodidae (Homoptera), species unidentified	MX	a	Hennessey, 2002
<i>Amorbia emigratella</i> Busck (Lepidoptera: Tortricidae)	MX, US	a, c	Ebeling, 1959
<i>Anthonomus</i> sp. (Coleoptera: Curculionidae)	MX	a, b	Adame, 1998
<i>Anastrepha fraterculus</i> (Wiedemann) (Mexico population) (Diptera: Tephritidae)	MX	k	Aluja, <i>et al.</i> , 2003; Baker <i>et al.</i> , 1944; Baker, 1945; Norrbom, In Press; Steck, 1991; Steck, 1999; Steck & Sheppard, 1993
<i>Anastrepha ludens</i> (Loew) (Diptera: Tephritidae)	MX	g	Aluja, <i>et al.</i> , In Press a APHIS, 1993c; Norrbom, In Press; Norrbom & Kim, 1988; Stone, 1942; 7 CFR 301.64
<i>Anastrepha obliqua</i> (Loew) (Diptera: Tephritidae)	MX	g, y	Norrbom, In Press; Aluja <i>et al.</i> , In Press a
<i>Anastrepha serpentina</i> (Wiedemann) (Diptera: Tephritidae)	MX	g, y	Norrbom, In Press; Aluja <i>et al.</i> , In Press a

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Anastrepha striata</i> Schiner (Diptera: Tephritidae)	MX	g	Uchoa & Zucchi, 2000; Ballou, 1936; Jiron, <i>et al.</i> , 1988; Norrbom, In Press; Norrbom & Kim, 1988; Aluja <i>et al.</i> , In Press a
<i>Anomala</i> sp.	MX	a, b	APHIS, 2004
<i>Apate monacha</i> F. (Coleoptera: Bostrichidae)	MX	a, g	Pierce, 1917
<i>Aphis gossypii</i> Glover (Homoptera: Aphididae)	MX, US	a, c	Ebeling, 1959
Probably <i>Apion</i> sp. (Coleoptera: Curculionidae)	MX	a, b	Adame, 1998
<i>Aspidiotis spinosus</i> (Comstock) (Homoptera: Diaspididae)	MX, US	a, c	Teliz, 2000
<i>Attelabus</i> sp. (Coleoptera: Curculionidae)	MX	a, b	Adame, 1998
<i>Brevipalpus australis</i> (Acarina: Tenuipalpidae)	MX	a	Garcia <i>et al.</i> , 1998
<i>Brochymena quadripustulata</i> F. (Heteroptera: Pentatomidae)	MX, US	a, c	Alvarez <i>et al.</i> , 1967; Henry & Froeschner, 1988
<i>Burtinus notatipennis</i> Stal (Heteroptera: Coreidae)	MX, US	a, c	Ebeling, 1959; Henry & Froeschner, 1988
<i>Calipitrimerus muesebecki</i> Keifer (Acarina: Eriophyidae)	MX, US	a	Baker <i>et al.</i> , 1996; Garcia <i>et al.</i> , 1998
<i>Capaneus humerosus</i> Distant (Heteroptera: Coreidae)	MX	a	Ebeling, 1959
<i>Caulophilus latinasus</i> Say (Coleoptera: Curculionidae)	MX, US	a, c	McKenzie, 1935
<i>Ceratitis capitata</i> (Wiedemann) (Diptera: Tephritidae)	MX	g, l, z	Liquido, <i>et al.</i> , 1998; Metcalf & Metcalf, 1993; White & Elson-Harris, 1992; 7 CFR 301.78; 7 CFR 318.13;
<i>Ceroplastes cirripediformis</i> Comstock (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
<i>Ceroplastes cistudiformis</i> Townsend & Cockerell (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
<i>Ceroplastes floridensis</i> Comstock (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
<i>Chrysodina</i> sp. (Coleoptera: Chrysomelidae)	MX	b	APHIS, 2004

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Chrysomphalus agavis</i> (Townsend & Cockerell) (Homoptera: Diaspididae)	MX, US	a, j	Ebeling, 1959
<i>Chrysomphalus aonidum</i> (L) (Homoptera: Diaspididae)	MX, US	a, c, j	Metcalf & Metcalf, 1993
<i>Chrysomphalus dictyospermi</i> (Morgan) (Homoptera: Diaspididae)	MX, US	a, c, j	Teliz, 2000
Cicadellidae, species unidentified (Homoptera)	MX	a, b	Hennessey, 2002
<i>Coccus hesperidum</i> (L) (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
<i>Conotrachelus aguacatae</i> Barber (Coleoptera: Curculionidae)	MX	z, g	Arellano, 1975; Wysoki <i>et al.</i> , 2002
<i>Conotrachelus perseae</i> Barber (Coleoptera: Curculionidae)	MX	z, g	APHIS, 1993b; Ebeling, 1959
<i>Conotrachelus</i> sp. (Coleoptera: Curculionidae)	MX	z, g	Adame, 1998; APHIS, 1993b
<i>Conotrachelus</i> sp. probably <i>flavangulus</i> Champion (Coleoptera: Curculionidae)	MX	a	Adame, 1998; APHIS, 1993b
<i>Copaxa multifenestrata</i> (Herrich-Schaffer) (Lepidoptera: Saturniidae)	MX	a, g	Teliz, 2000
Possibly <i>Copturomimus</i> sp. (Coleoptera: Curculionidae)	MX	a	Adame, 1998
<i>Copturus aguacatae</i> Kissinger (Coleoptera: Curculionidae)	MX	z, g	APHIS, 1993b; MacGregor & Gutierrez, 1983; APHIS, 2004
<i>Copturus constrictus</i> Champion (Coleoptera: Curculionidae)	MX	a	Sleeper, 1978
<i>Corthylus nudus</i> Schedl (Coleoptera: Scolytidae)	MX	a	MacGregor & Gutierrez, 1983
Curculionidae, unidentified species (Coleoptera)	MX	a, b	Adame, 1998
<i>Cyclocephala</i> sp. (Coleoptera: Scarabaeidae)	MX	b	APHIS, 2004
Probably <i>Cylindrocopturus</i> sp. (Coleoptera: Curculionidae)	MX	a, b	Adame, 1998
<i>Dallasiellus</i> sp. (Hemiptera: Cydnidae)	MX	b, x	APHIS, 2004

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Deloyala guttata</i> (Olivier) (Coleoptera: Chrysomelidae)	MX, US	a, c	APHIS, 2004; Ebeling, 1959
<i>Diabrotica porracea</i> Harold (Coleoptera: Chrysomelidae)	MX	a, g, x	APHIS, 2004
<i>Diaprepes abbreviatus</i> (L.) (Coleoptera: Curculionidae)	MX, US	a, g	Bennett, 1985
<i>Diaspidiotus perniciosus</i> (Comstock) (Homoptera: Diaspididae)	MX, US	a, c, j	Teliz, 2000
<i>Diaspidiotus</i> sp. (Homoptera: Diaspididae)	MX	b, x	APHIS, 2004
Diaspididae, unidentified species (Homoptera)	MX	b	APHIS, 2004
<i>Diaspis cocois</i> Lichtenstein (Homoptera: Diaspididae)	MX, US	a, c, j	Teliz, 2000
<i>Dysdercus obliquus</i> (Herrich-Schaeffer) (Heteroptera: Pyrrhocoridae)	MX, US	a, c	Ebeling, 1959; Henry & Froeschner, 1988
<i>Eotetranychus sexmaculatus</i> (Riley) (Acarina: Tetranychidae)	MX, US	a, c	Bolland <i>et al.</i> , 1998; Garcia <i>et al.</i> , 1998
<i>Estigmene</i> sp. (Lepidoptera: Arctiidae)	MX, US	a, b, c	APHIS, 2004
<i>Farinococcus olivaceus</i> (Cockerell) (Homoptera: Pseudococcidae)	MX	a	Ebeling, 1959
Formicidae species undetermined (Hymenoptera)	MX	a	Hennessey, 2002
<i>Frankliniella bruneri</i> Watson (Thysanoptera: Thripidae)	MX	a, g	Teliz, 2000
<i>Frankliniella cephalica</i> Hood (Thysanoptera: Thripidae)	MX, US	a, c	Ebeling, 1959
<i>Frankliniella chamulae</i> Johansen (Thysanoptera: Thripidae)	MX	a	Teliz, 2000
<i>Frankliniella difficilis</i> Hood (Thysanoptera: Thripidae)	MX	a	Teliz, 2000
<i>Frankliniella minor</i> Moulton (Thysanoptera: Thripidae)	MX	a	Teliz, 2000
<i>Franklinothrips vespiformis</i> (Crawford) (Thysanoptera: Aeolothripidae)	MX, US	a, c	CPC, 2003; Teliz, 2000
<i>Hansenia pulverulenta</i> (Guerin-Meneville) (Homoptera: Flatidae)	MX	a	MacGregor & Gutierrez, 1983

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Heilipus albopictus</i> Champion (Coleoptera: Curculionidae)	MX	a	MacGregor & Gutierrez, 1983
<i>Heilipus lauri</i> Bohemann (Coleoptera: Curculionidae)	MX	z, g	APHIS, 1993b; Ebeling, 1959
<i>Heliothrips haemorrhoidalis</i> (Bouche) (Thysanoptera: Thripidae)	MX, US	a, c	Ebeling, 1959
<i>Hemiberlesia diffinis</i> (Newstead) (Homoptera: Diaspididae)	MX	a, g, j	Nakahara, 1982; Teliz, 2000
<i>Hemiberlesia lataniae</i> (Signoret) (Homoptera: Diaspididae)	MX, US	a, c, j	Nakahara, 1982
<i>Hemiberlesia rapax</i> (Comstock) (Homoptera: Diaspididae)	MX, US	a, c, j	Nakahara, 1982
<i>Hemiberlesia</i> sp. (Homoptera: Diaspididae)	MX	b, j, x	APHIS, 2004
<i>Icerya montserratensis</i> Riley & Howard (Homoptera: Margarodidae)	MX	a, g	Ebeling, 1959
<i>Icerya purchasi</i> Maskell (Homoptera: Margarodidae)	MX, US	a, c	Ebeling, 1959
<i>Idona minuenda</i> (Ball) (Homoptera: Cicadellidae)	MX, US	a, c	Teliz, 2000
<i>Idona</i> spp. (Homoptera: Cicadellidae)	MX, US	a	Ebeling, 1959
<i>Largus cinctus</i> Herrich-Schaeffer (Heteroptera: Largidae)	MX, US	a, c	Ebeling, 1959; Henry & Froeschner, 1988
<i>Leptoglossus phyllopus</i> (L) (Heteroptera: Coreidae)	MX US	a, c	Ebeling, 1959
<i>Leptothrips mcconnelli</i> (Crawford) (Thysanoptera: Phlaeothripidae)	MX	a	Teliz, 2000
<i>Ligyris</i> sp. (Coleoptera: Scarabaeidae)	MX	a, b, x	APHIS, 2004
<i>Liothrips perseae</i> (Watson) (Thysanoptera: Phlaeothripidae)	MX	a	MacGregor & Gutierrez, 1983; Nakahara, 1995
<i>Melanaspis aliena</i> (Newstead) (Homoptera: Diaspididae)	MX	a, j	Nakahara, 1982
<i>Melipona testacea cupira</i> Smith (Hymenoptera: Meliponidae)	MX	a	Ebeling, 1959
<i>Metcalfiella monogramma</i> (Germar) (Homoptera: Membracidae)	MX	a, g	Ebeling, 1959

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Mycetaspis personata</i> (Comstock) (Homoptera: Diaspididae)	MX, US	a, c, j	Nakahara, 1982
<i>Neohydatothrips signifier</i> Preisner (Thysanoptera: Thripidae)	MX	a	Hoddle, 1999
<i>Neosilba batesi</i> Curran (Diptera: Lonchaeidae)	MX, US	a	Ahlmark & Steck, 1997; Aluja <i>et al.</i> , In Press a; Hennessey, 2002; White & Elson-Harris, 1992
<i>Nipaecoccus nipae</i> (Maskell) (Homoptera: Pseudococcidae)	MX, US	a, c	Ebeling, 1959
<i>Oligonychus yothersi</i> (McGregor) (Acarina: Tetranychidae)	MX, US	a	MacGregor & Gutierrez, 1983; McMurtry, 1985
<i>Oligonychus perseae</i> Tuttle, Baker & Abbatiello (Acarina: Tetranychidae)	MX, US	a, c	Teliz, 2000
<i>Oligonychus platani</i> (McGregor) (Acarina: Tetranychidae)	MX, US	a, c	MacGregor & Gutierrez, 1983; McMurtry, 1985
<i>Oligonychus punicae</i> (Hirst) (Acarina: Tetranychidae)	MX, US	a, c	McMurtry, 1985
<i>Papilio garamas garamas</i> Hubner (Lepidoptera: Papilionidae)	MX, US	a	Teliz, 2000, USGS, 2003
<i>Paraleyrodes goyabae</i> (Goeldi) (Homoptera: Aleyrodidae)	MX	a	Teliz, 2000
<i>Paraleuroides</i> sp. near <i>goyabae</i> (Goeldi) (Homoptera: Aleyrodidae)	MX	a	Ebeling, 1959
<i>Phyllophaga</i> sp. (Coleoptera: Scarabaeidae)	MX	a, b, x	APHIS, 2004
<i>Pinnaspis strachani</i> (Cooley) (Homoptera: Diaspididae)	MX, US	a, c, j	Teliz, 2000
<i>Pityophthorus</i> sp. (Coleoptera: Scolytidae)	MX	a (in pallets), b, x	APHIS, 2004
<i>Planococcus citri</i> (Risso) (Homoptera: Pseudococcidae)	MX, US	a, c	Ebeling, 1959
<i>Polydrusus</i> sp. (Coleoptera: Curculionidae)	MX	a, b	Adame, 1998
<i>Polyphagotarsonemus latus</i> (Acarina: Tarsonemidae)	MX, US	a, c	Garcia <i>et al.</i> , 1998; Jeppson <i>et al.</i> , 1975
<i>Pseudacysta perseae</i> (Heidemann) (Heteroptera: Tingidae)	MX, US	a, c	MacGregor & Gutierrez, 1983; Henry & Froeschner, 1988

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Pseudobaris</i> sp. (Coleoptera: Curculionidae)	MX	a	Adame, 1998
<i>Pseudococcus longispinus</i> (Targioni-Tozzetti) (Homoptera: Pseudococcidae)	MX, US	a, c	Ebeling, 1959
Pseudococcidae, unidentified species (Homoptera)	MX	a, b	Hennessey, 2002
<i>Pseudophlothrips perseae</i> (Watson) (Thysanoptera: Phlaeothripidae)	MX	a	Teliz, 2000
Psychidae species unidentified (Lepidoptera)	MX	a, b	Hennessey, 2002
<i>Pulvinaria simulans</i> Cockerell (Homoptera: Coccidae)	MX	a	Ebeling, 1959
<i>Pyrrhopyge chalybea</i> Scudder (Lepidoptera: Hesperidae)	MX	a, g	Diaz, 1976
<i>Rhyssomatus</i> sp. (Coleoptera: Curculionidae) (unconfirmed)	MX	a	Adame, 1998
<i>Saissetia coffeae</i> (Walker) (Homoptera: Coccidae)	MX, US	a, c	Metcalf & Metcalf, 1993
<i>Saissetia hemisphaerica</i> (Targioni) (Homoptera: Coccidae)	MX, US	a	Ebeling, 1959
<i>Scaphytopius</i> sp. (Homoptera: Cicadellidae)	MX	a, g	Ebeling, 1959
<i>Scirtothrips aceri</i> (Moulton) (Thysanoptera: Thripidae)	MX, US	a	Hoddle, no date; Teliz, 2000
<i>Scirtothrips aguacatae</i> Johansen & Mojica (Thysanoptera: Thripidae)	MX	a	Teliz, 2000
<i>Scirtothrips kupandae</i> Johansen & Mojica (Thysanoptera: Thripidae)	MX	a	Teliz, 2000
<i>Scirtothrips perseae</i> Nakahara (Thysanoptera: Thripidae)	MX, US	a	Nakahara, 1997; Teliz, 2000
<i>Stenoma catenifer</i> Walsingham (Lepidoptera: Oecophoridae)	MX	z, g	Ebeling, 1959
<i>Tegolophus perseafloreae</i> Keifer (Acarina: Eriophyidae)	MX, US	a	Baker <i>et al.</i> , 1996; Garcia <i>et al.</i> , 1998
<i>Trialeurodes floridensis</i> (Quaintance) (Homoptera: Aleyrodidae)	MX, US	a, c	Teliz, 2000
<i>Trialeurodes similis</i> Russell (Homoptera: Aleyrodidae)	MX	a, c	Ebeling, 1959
<i>Trioza anceps</i> Tuthill (Homoptera: Psyllidae)	MX	a, g	MacGregor & Gutierrez, 1983

Appendix A – Pest List

Table A-2: Arthropods			
Genus species Author (Order: Family)	Distribution¹	Comments²	References
<i>Umbonia crassicornis</i> (Amyot & Serville) (Homoptera: Membracidae)	MX, US	a, c	Teliz, 2000
<i>Velataspis dentata</i> (Hoke) (Homoptera: Diaspididae)	MX, US	a, c, j	Teliz, 2000

¹ Distribution legend: MX = Mexico; US = United States.

² Comments:

- a = Pest associated with plant part other than commodity, or in rotting fruit on ground.
- b = Further analysis not possible because species not identified
- c = Listed in catalogue of pest interceptions as non-reportable (APHIS, 2003c)
- g = Listed in the catalogue (APHIS, 2003c, APHIS, 2004) of intercepted pests as reportable.
- j = Armored scale insect: no quarantine action taken on fruit for consumption because "...armored scales in general have a low probability of establishment from infested shipments of commercial fruit" (ARS, 1985).
- k = There is a taxonomic problem with the species. The Mexico population of this species does not use avocado fruit as a natural host. Some South American populations do infest avocado.
- l = Pest excluded by official control from area of production and processing.
- x = Multiple APHIS interceptions exist (APHIS, 2003c; APHIS, 2004).
- y = Original studies have not demonstrated that avocado is a natural host in the field, according to the references.
- z = Pest is known to commonly attack or infect fruit. It would be reasonable to expect that the pest may remain with the fruit during processing and shipping.

Appendix B: Review of the Biology of Selected Pests

This review of the biology of selected quarantine pests is an update of information in attachments 1 and 2 of the initial pest risk assessment: “Risk Management Analysis: A Systems Approach for Mexican Avocados” (USDA, 1995b). Key evidence from those documents was revised and updated.

1. *Conotrachelus perseae* and *C. aguacatae* (seed weevils)

a. Distribution -These seed weevils are reported to occur in Mexico and Central American as far south as Panama (Whitehead, 1979a, b; Ebeling, 1959). In Mexico, *C. perseae* is reported in the states of Michoacán, Puebla, Veracruz, and Jalisco; *C. aguacatae* is reported for the states of Coahuila, Jalisco, Michoacán, Nayarit, Queretaro, Guanajuato, Puebla, and Morelos (Whitehead, 1979a, b and Sanidad Vegetal, 1992), and is prevalent at high elevations. FAO (1986) reports its occurrence in Mexico

b. Host -The only host reported for *C. perseae* and *C. aguacatae* is *P. americana* (avocado). Interceptions of *Conotrachelus* by PPQ indicate that the “Creole type of avocado” (Mexican race) seems to be most heavily attacked (USDA, 1941). Sanidad Vegetal (1992) reports that both of these weevils prefer the Mexican race of avocado, but also attack the variety ‘Hass.’ Since *Conotrachelus* is reported as a pest of avocado in Central America, it should be assumed that various varieties of the Guatemalan race of avocado could be attacked.

c. Biology -Eggs are deposited on the young undeveloped fruit and the larva feed in the seed until they are fully developed. When fully developed the larva exit the fruit and pupate in the soil. Sanidad Vegetal (1992) reports that one to four larvae of *C. perseae* develop in each infested fruit, however, Sleeper (1978) reports that up to 28 larvae can be found in one fruit. Sanidad Vegetal (1992) and Sleeper (1978) also states that the damaged fruit falls to the ground before the fruit is fully developed. PPQ has intercepted larvae in various stages of development in avocado fruits being smuggled into the United States; this indicates that at least a portion of the infested fruits developed to a marketable stage (USDA 1941). The adults are active at night and feed on the fruits, leaves, and stems of avocado trees. In Mexico, *C. perseae* is reported to have two generations per year.

d. Economic Importance -Ebeling (1959) ranked both of these weevils as minor pests of avocados. Arellano (1975) reports this pest tunnels into/through the seeds of *P. americana*. Sanidad Vegetal (1992) reported that on neglected farms the infestation rate could be between 7 and 18 percent of the fruit and as high as 66 percent on Creole trees. Field controls reported by Sanidad Vegetal include foliage and ground application of pesticides, raking of the ground to expose the pupae, and the collection and destruction of fallen fruit (Sanidad Vegetal 1992).

2. *Heilipus lauri* (a seed weevil)

a. Distribution -This pest is reported to occur in Mexico and south to (at least) Colombia. In Mexico, it is reported to be in the states of Hidalgo, Mexico, Morelos, Veracruz, Guerrero, Puebla and Tlaxcala (Garcia, 1962; Sanidad Vegetal, 1992; MacGregor, 1983). This pest is also reported at high elevations.

b. Host -Sanidad Vegetal (1992) reports that it prefers Creole avocado trees (Mexican race), but also attacks improved avocado varieties.

c. Biology -Ebeling (1959) reports the biology of this pest. He states that there is one generation per year. The winter is spent in the adult stage, and adults deposit eggs in the developing fruit in

May, June, and July. The larvae tunnel to the seed where they feed and pupate. After the adults leave the fruit they feed on the leaf, bud, sprout, and fruit of their host. Sometimes pupation takes place in the soil from fallen fruit. Sanidad Vegetal (1992) states that there is an average of two larvae per infested seed and that there were two generations in a 15.5-month period in Morelos, where this pest was studied.

d. Economic Importance -Ebeling (1959) ranked this pest as a major pest of avocado; larvae feed seeds, adults on leaves. In certain areas of Mexico, it can cause up to 80 percent fruit loss (Garcia, 1962). Sanidad Vegetal (1992) reported various field controls, including foliar application of pesticides directed at the adults, weed control, and the destruction of fallen fruit.

3. *Copturus aguacatae* (an avocado stem weevil)

a. Distribution -This weevil is known to be from the Mexican states of Guerrero, Puebla, Morelos, and Michoacán (Whitehead, 1979b; Kissinger, 1957; Macgregor, 1983).

b. Host- The only host reported was *P. americana* (Kissinger, 1957, Muniz, 1959). Adults reared from smuggled avocado fruit intercepted at the Mexican border were *C. aguacatae*. In recent years, larvae have been detected in smuggled ‘Hass’ avocado fruit intercepted by PPQ from Mexico, mainly El Paso, Texas.

c. Biology -The weevil bores into the small new stems and branches, but can affect the older branches or fruits near the peduncle end at high population densities. Eggs are laid in holes bored by the female in the bark of the plant (Garcia et al., 1998). A maximum of eight eggs are laid in a group by the female. Oviposition occurs mostly in April and May by the first generation and in October and November by the second generation, although adults emerge from May to early July and from November to February (Muniz, 1959).

d. Economic Importance -This species and related weevils have been reported to cause great destruction to avocado trees. The boring of this pest causes die back of the branches and uncontrolled infestations that can cause a reduction in the size of the tree. Ebeling (1959), Sleeper (1978), and Whitehead (1979b) call this a major pest. Muniz (1959) states secondary infections of viruses, bacteria and fungi may occur. *C. aguacatae* and related pests have been controlled by repeated foliar applications of contact pesticides.

4. *Stenomoma catenifer* (avocado seed moth)

a. Distribution -This pest is reported to occur in Mexico south to Brazil (Acevedo, 1973), and has recently been reported in Guyana (Cervantes-Peredo *et al.*, 1999). In Mexico, it is reported in the states of Veracruz, Tamaulipas, Oaxaca, Chiapas, Nuevo Leon, Guerrero, and Colima (Acevedo, 1973; Macgregor, 1983). It is not reported from Michoacán.

b Host -This moth is reported to attack *P. scheidiana* (chinini) and *Beilschmedia* sp. (anayo) (Acevedo, 1973; USDA, 1980). It also attacks *P. americana* (cultivated avocado), and has been reported on the varieties ‘Choquette’, ‘Hall’, ‘Lula’, ‘Booth 7’, ‘Booth 8’, and ‘Carmelita’ (Acevedo 1973; Ebeling, 1959). Recently, it was reported on *Chlorocardium rodiei* (Greenheart), the most important timber tree in Guyana (Cervantes Peredo *et al.*, 1999).

c. Biology -This moth spends the winter as an adult in the soil or leaf litter. In the spring, the female mates and deposits eggs on the stem and fruit of its hosts. Adults usually remain hidden during the day and fly erratically around the host at night. The larvae bores in the stem and fruit. Within the fruit, *S. catenifer* feeds on the pulp for several days before moving into the seed, where the main part of its development takes place. Pupation takes place outside of the fruit, in or on the soil. The number of generations per year varies, depending on the availability of fruit

(Acevedo, 1973; Ebeling, 1959; USDA, 1980).

d. Economic Importance -This is one of the most serious avocado pests in the world. Ebeling (1959) rates it as a major pest of avocado. The larvae damage the terminal twigs and can often kill young trees. The damage on stems can also result in fruit drop. The damage occurs about one month after the fruit forms, and makes the fruit unmarketable (Acevedo, 1973). In Venezuela, it is considered one of the most important pests of avocado (Boscan and Godoy, 1982). In tropical areas of Mexico, this pest is a limiting factor for avocado production. A fruit infestation rate of 94 percent has been reported, and one larva can destroy a fruit. In one study, it required 14 treatments of pesticide per season to eliminate damage from this pest (Acevedo, 1973).

5. *Anastrepha ludens*, *A. striata*, and *Ceratitis capitata* (Fruit flies).

Avocado is not considered a host for *Anastrepha serpentina*, *A. fraterculus* (Mexico populations) and *A. obliqua* (Norrbon, In Press) that are listed in Table A-2.

a. Distribution- These fruit flies have a range that includes tropical or subtropical areas.

Anastrepha striata occurs from Mexico to Brazil and outbreaks have occurred in Texas and California. *Anastrepha ludens* occurs from northern Mexico to Costa Rica, and outbreaks have occurred in Texas and California (Foote et al., 1993; Sequeira et al., 2001). *Ceratitis capitata* occurs over southern Europe and throughout Central and South America (CPC, 2002), it is established in Hawaii, and outbreaks have occurred in Florida and California.

b. Hosts--*Anastrepha striata* infests *Prunus persica*, *Persea*, *Eugenia*, *Mangifera*, *Passiflora*, *Diospyros*, *Manihot*, and other genera in multiple families. *Anastrepha ludens* infests *Prunus persica*, *Annona*, *Casimiroa*, *Citrus*, *Cydonia*, *Mammea*, *Mangifera*, *Persea*, *Psidium*, *Pyrus* and other genera representing over five families (Norrbon, In Press). *Ceratitis capitata* infests over 100 crop and non-crop species, including *Opuntia*, *Persea*, *Prunus*, *Malus*, *Capsicum*, and others in over 10 families (Liquido et al., 1998).

c. Biology- These fruit flies have been documented to have continuous generations within their ranges. Females can live for several months and are capable of laying over 100 eggs each. These fruit flies have a life cycle of less than 45 days, under optimum conditions, a capability to spread naturally by flight over 20 km per year, and a capability to spread worldwide in commerce. Eggs are laid under or within the peel of fruits of various stages of maturation; the larvae bore through the pulp until pupation, which occurs after dropping to the soil (CPC, 2002; Fletcher, 1989; Foote et al., 1993; Liquido et al., 1998; Norrbom, In Press; Sequeira et al., 2001; White and Elson-Harris, 1994).

d. Economic importance- These species are regulated pests (APHIS, 2002); therefore, their establishment in the United States could trigger quarantines against exports. *Anastrepha striata* is a primary pest of guava in Venezuela, reducing the yield and quality of fruit (Marin Acosta, 1973). *Anastrepha ludens* infestations in citrus could cause a decrease in yield and quality in the United States valued at \$70 million (1975 prices) (Andrew et al, 1977). *Ceratitis capitata* infestation may cause yield and quality losses requiring up to \$341 million in additional production costs if it becomes established in California (CDFA, 2003). Eradication of outbreaks is an annual expense incurred by USDA and the states, and if an outbreak is detected, all of these species would be expected to trigger APHIS eradication programs involving area-wide spray programs, as has occurred in Florida, Texas, and California (Sequeira et al., 2001).

This section on the biology of selected pests was drafted by C. E. Miller, RAS, PPD, APHIS, September 1992 and revised by L. Duffie, USDA-APHIS-PPQ-CPHST, January 2003, and M.

Hennessey, December, 2003 and February, 2004. References for this section may be found in the section entitled “References”.

Appendix C: Review of *Anastrepha* Species

Previous analysis and much of the focus from stakeholders (as per the Administrative Record on comments regarding proposed rules for avocado importation from Mexico) was on the potential of introduction of *Anastrepha* spp. fruit flies with ‘Hass’ avocados. The status of ‘Hass’ avocados as hosts of *Anastrepha* spp. fruit flies has been the focus of intense research. From 1992 to 1994 Martinez *et al.* (1993) dissected 153.5 tons of avocado fruit (618,975 fruit) by randomly cutting one cm slices of selected fruit from nine packinghouses in Michoacán. No fruit flies were detected to be infesting avocados even though trapping data showed that fruit flies were present in the area attacking other hosts. In a related study, Enkerlin *et al.* (1993) evaluated the host status of ‘Hass’ avocados before and after they were removed from the tree. They found that avocados were not naturally infested when attached to the tree. Furthermore, when fruit was still attached and artificially infested with fruit flies, oviposition did occur, but larvae did not develop. Researchers [Enkerlin *et al.* (1993); Santiago Martinez *et al.*, 1993] reported that biochemical processes were probably responsible for the lack of viable eggs in fruit that was attached to the tree. (This resistance rapidly disappeared after harvest.) Enkerlin *et al.* (1993) were able to obtain viable larvae under laboratory conditions with artificial infestations of harvested fruit, if the fruit was mature (more than 21.5% dry matter) and at least 3 hours elapsed after harvest.

Recent research by Aluja *et al.* (In Press a) conducted during August-October, 2001, and April-June, 2002 combined detailed field observations and laboratory studies. Field studies were conducted in 2001 and 2002 at three different altitudes (1200-1440, 1600-1800, and 2000-2100 m above sea level) that encompassed all key production areas in the state of Michoacán, Mexico. In the field experiments, ready-to-harvest fruit of Hass’ avocados randomly collected from six orchards at the three different representative altitudes (76,950 fruit) did not reveal fruit fly infestations. Additionally, field cages were used to artificially infest fruit attached to branches (5,200 fruit) in commercial orchards with large numbers of viable fruit flies (wild and lab reared flies). Fruit fly larvae were found in two fruits. These two infested fruits were observed over the following days, but viable offspring did not result (that is, underweight pupae were formed, but adults did not emerge). Finally, for the field observations, mature avocados were placed on trays on the orchard floor (3,600 fruit). Three fruits were infested by the loncheid decomposer, *Neosilba batesi* (Diptera: Lonchaeidae), but had no fruit fly infestations. This finding further supports the low likelihood of infestation by *Anastrepha*, even in fallen fruit.

As part of the observations by Aluja *et al.* (In Press a), fruit was sampled from packinghouses (1,620 fruit) and no infestation was detected. In laboratory trials, fruit was artificially exposed to large numbers of mated females of four different species of *Anastrepha*: *A. serpentina*, *A. ludens*, *A. striata*, and *A. obliqua*. The conditions of exposure varied from “choice” studies and “no-choice” studies in laboratory conditions. The no-choice studies included only ‘Hass’ avocados. The choice studies included ‘Hass’ avocados and known hosts. Whereas oviposition was attempted, infestation by the different fruit flies did not occur. In the choice trials, the known hosts were visited more frequently and had infestations that resulted in viable offspring. Observations on the physiological responses to oviposition in ‘Hass’ cultivar avocados suggest epicarp regeneration and callus formation that inhibits proper larval development. The latter

observations on the resistance mechanisms in avocados by Aluja *et al.* (In Press a) were consistent with observations by Smith (1973), Armstrong *et al.* (1993), Martinez *et al.* (1993) and Enkerlin *et al.* (1993).

From the above studies, and from the rigor of the most recent study by Aluja *et al.* (In Press a), (all observations and design phases were overseen by USDA and independent reviewers) we conclude that commercially produced fruit from Michoacán, Mexico are considered to be a low-likelihood pathway for *Anastrepha* spp. Previous assessments (USDA, 1995a) included *Anastrepha* spp. as part of the quarantine pests that were considered in greater detail, although avocados were considered non-hosts or at best, poor hosts. Those earlier assessments concluded that there was a very low probability of association of *Anastrepha* with the 'Hass' avocado imports (USDA, 1995a, b; 2001b).

Appendix D - Quantitative Risk Assessment Model

This document presents the methodology and results of the quantitative analysis.

Summary

In 1993, APHIS authorized entry of Mexican avocado fruit into Alaska. In 1997 'Hass' avocados were allowed to be shipped, from Michoacán, Mexico, to 19 states and the District of Columbia, and the allowable shipping season was November 15 to February 15. Since November 2001 (according to CFR §319.56-2ff: "Administrative instructions governing movement of 'Hass' avocados from Michoacán, Mexico, to approved States"), 'Hass' avocados have been allowed to be shipped to 31 states and the District of Columbia, and the allowable shipping season is October 15 to April 15.

This assessment responds to the request to expand the importation of fresh 'Hass' variety avocado fruits (*Persea americana*) grown in the state of Michoacán, Mexico, into all states during all months of the year.

APHIS conducted a screening analysis on previously identified avocado pests known to occur in Mexico that may have potential economic importance in the United States. The screening involved the elimination of non-quarantine pests and non-pathway pests from the list, and resulted in the identification of the following pathway pests of quarantine significance.:

1. three seed weevils: *Conotrachelus aguacatae*, *Conotrachelus perseae*, and *Heilipus lauri*;
2. one stem weevil: *Copturus aguacatae*;
3. one seed moth: *Stenoma catenifer*; and
4. fruit flies: *Anastrepha ludens*, *A. striata*, and *Ceratitis capitata*

Since 1997 approximately 300 million 'Hass' avocados have been imported from Mexico under a systems management protocol that includes packinghouse and port of entry inspections. To date, more than ten million fruit have been cut and inspected as part of the avocado export program, and no quarantine pests have been detected.

The proposed expanded avocado importation program will involve all States, including susceptible states.

This quantitative risk assessment (QRA) focuses on the following pests:

1. three seed weevils: *Conotrachelus aguacatae*, *Conotrachelus perseae*, and *Heilipus lauri*;
2. one stem weevil: *Copturus aguacatae*; and
3. one seed moth: *Stenoma catenifer*
4. fruit flies: *Anastrepha ludens*, *A. striata*, and *Ceratitis capitata*.

Two quantitative evaluations were performed as follows:

1. **Avocado Pests:** The seed moth, stem weevil and three seed weevils are exclusively avocado pests, and are dealt with as one quantitative analysis.
2. **Fruit Flies:** The fruit flies can infest other fruit aside from Avocados, so they are dealt with as a second quantitative analysis.

The QRA estimates the annual number of infested avocados entering the United States, the annual number of infested avocados entering susceptible areas in the United States, and the annual number of infested avocados discarded in susceptible areas.

This assessment does not evaluate the individual effectiveness of the systems mitigations in reducing the phytosanitary risks to the United States. It considers the individual mitigations collectively, and assumes that the current systems mitigations will remain in place at the same level.

This assessment utilizes the results of six years of surveys to estimate the proportion of imported avocados that are infested. It then estimates:

- 1) The annual number of infested fruit likely to enter the United States by computing the product of the annual number of avocados likely to be imported, and the proportion of imported avocados that are infested;
- 2) The annual number of infested fruit likely to enter susceptible areas (areas where host material is available) in the United States by computing the product of the annual number of infested fruit likely to enter the United States, and the proportion of avocados consumed in susceptible areas.
- 3) The annual number of infested fruit likely to be discarded in susceptible areas in the United States by computing the product of the annual number of infested fruit likely to enter susceptible areas, and the proportion of avocados discarded (those that are not eaten, and do not go to the garbage, but are thrown outside).

APHIS has developed a risk assessment model that is presented in this document. The risk assessment predicts that 114 million to 1.8 billion ‘Hass’ avocados will be imported annually from Mexico. The most likely number ranges uniformly from 423 million to 635 million.

Following is a summary of the results of twenty thousand Monte Carlo iterations of the risk assessment model using @Risk (Palisade Corporation, Newfield, New York) and Excel (Microsoft Inc., Redmond, Washington).

The 95% Confidence Level for Results of the Pathway Model

	Description of parameter	Fruit Fly Infested	Arthropod Pest Infested
P1	Proportion of Mexican avocados that are infested with a pathway arthropod pest	0.52/1,000,000	0.52/1,000,000
P2	Proportion of infested avocados that enter susceptible areas in the United States	24/100	36.4/100
P3	Proportion of infested avocados that are discarded	5%	5%
Q1	Annual number of infested avocados that enter the United States	387	387
Q2	Annual number of infested avocados that enter susceptible areas in the United States	143	49
Q3	Annual number of infested avocados that are discarded in susceptible areas in the United States	8	3

There is a 95 percent confidence of the parameter value not exceeding the 95 percentile value.

METHODOLOGY

The study is comprised of an analysis of the pathway of commercial exports from Mexico of fresh ‘Hass’ avocados, produced and imported in compliance with USDA regulations. The Quantitative Risk Assessment (QRA) was conducted to identify what can go wrong and how likely it is to happen.

The risk assessment provides a method for measuring phytosanitary risk and providing information to facilitate or support decision-making tasks.

Based on the probabilistic scenario analysis methodology, the risk assessment process involved:

- A. Identifying the phytosanitary hazards;
- B. Stating the questions to be answered;
- C. Developing scenario trees (conceptual outlines), labeling the scenario trees and assigning units;
- D. Stating assumptions;
- E. Gathering and documenting the evidence, and Assigning values to the branches of the scenario trees;
- F. Performing calculations to summarize the likelihood of the hazards occurring

A. Phytosanitary Hazards

APHIS conducted a screening analysis on previously identified avocado pests known to occur in Mexico that may have potential economic importance in the United States. The screening involved the elimination of non-quarantine pests and non-pathway pests from the list and resulted in the identification of pathway pests of quarantine significance. APHIS has identified the following quarantine pests that could pose a threat to U.S. agriculture if introduced into susceptible areas in the United States via this importation:

1. seed weevils:
 - a. *Conotrachelus aguacatae*,
 - b. *Conotrachelus perseae*, and
 - c. *Heilipus lauri*
2. stem weevil: *Copturus aguacatae*
3. seed moth: *Stenoma catenifer*; and
4. fruit flies: *Anastrepha ludens*, *A. striata*, and *Ceratitis capitata*

The phytosanitary hazard (or unwanted event) is the introduction of any one of these pests into susceptible areas in the United States.

B. Questions to be answered

A quantitative risk assessment usually answers the questions: “What is the likelihood of the hazard occurring, what is its magnitude/frequency, and what are the consequences?” This risk assessment estimates the likelihood of introduction of any pathway pest into susceptible areas in the US. However, because of lack of quantitative data, the end point of introduction was terminated at discarding for the quantitative portion. Therefore, the quantitative risk assessment estimates the likelihood of entry of the avocado pests into susceptible areas. We estimate two quantitative endpoints: a) the number of infested avocados reaching the United States each year, b) the number of infested avocados reaching avocado producing regions in the United States each year, and c) the number of infested fruits being discarded in susceptible areas.

Due to the lack of quantitative data, the additional steps leading to the establishment of a pest in the United States are evaluated using qualitative evidence.

This quantitative risk assessment answers the following specific questions about fruit flies, seed weevils, stem weevil, and seed moth:

1. What proportion of the 'Hass' avocados entering the United States is infested?
2. What proportion of imported 'Hass' avocados enter susceptible areas?
3. How many infested 'Hass' avocados will enter the United States annually?
4. How many infested avocados enter susceptible areas in the United States on an annual basis?

C. Scenario Tree

This risk assessment estimates:

1. the annual number of infested avocados entering the United States, and
2. the annual number of infested avocados entering susceptible areas in the United States.
3. the annual number of infested avocados that are discarded in susceptible areas in the United States.

Infested 'Hass' avocados from Mexico could reach and be discarded in susceptible areas in the United States if:

- A. A quantity of avocados are harvested in Mexico for export to the United States, and
- B. a proportion of them are still infested after systems mitigations, and
- C. some infested avocados are distributed to susceptible areas, and
- D. some of those infested avocados are discarded in the susceptible areas.

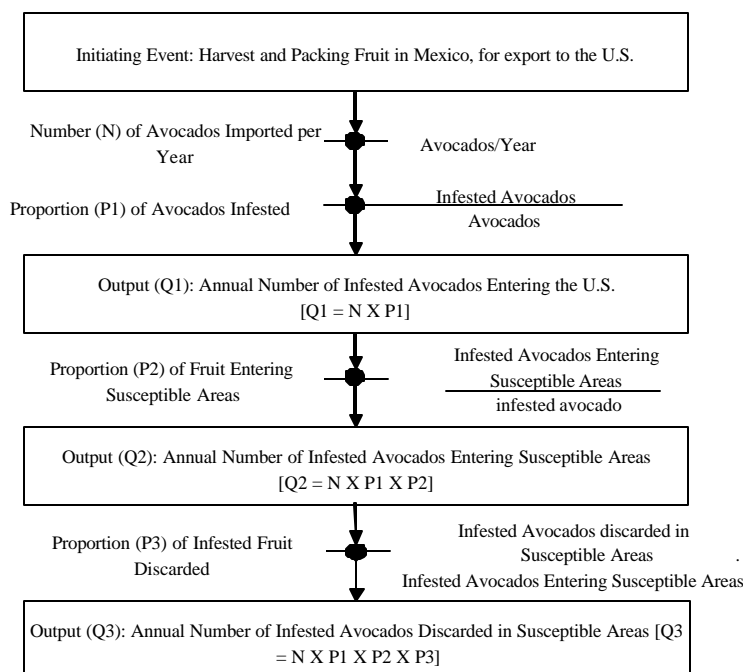
The annual number of infested avocados that enter and are discarded in susceptible areas is based on:

- a) N, the potential quantity of avocados to be imported from Mexico, and
- b) P1, the pest infestation rate (as determined by survey/inspection), and
- c) P2, the fraction of avocados likely to end up in susceptible areas, and
- d) P3, the fraction of avocados likely to be discarded into the environment by consumers

A scenario tree representing the generic pathway is presented on the following page.

A scenario tree is a pictorial representation of all possible outcomes of an initiating event. A risk pathway tree depicts that subset of pathways that lead to manifestation of a hazard. The risk pathway tree is a pictorial representation of what could go wrong in order for infested 'Hass' avocados from Mexico to reach avocado producing areas.

Figure 1. Risk Pathway Tree



D. Quantitative Model Assumptions:

The following assumptions were made in the quantitative model:

1. Infested avocados are distributed homogeneously throughout the avocado population. In other words, each avocado is equally likely to be infested. The probability that any given avocado is infested is defined stochastically by a probability distribution.
2. The process of survey/inspection is a binomial process.
3. The proportion of avocados reaching susceptible areas in the United States was estimated from the proportion of the total population represented in those areas, and the relative per-capita avocado consumption of individuals in those areas.
4. The effectiveness of specific mitigations is not considered in this quantitative model. However, it is assumed that the mitigations described in the keys safeguards sections will remain in place.
5. The prevalence of pest infestation in April to October (the proposed addition to the shipping season) is the same as the prevalence in October to April (the current shipping season).
6. The levels of inspection and fruit cutting in April to October (the proposed addition to the shipping season) is the same as the levels of inspection and fruit cutting in October to April (the current shipping season).
7. The systems approach remains in place in at least the current level of intensity.

The evidence used, and manner of estimation of each of the parameters is presented below.

E. Parameter Estimates

Parameter Estimate Node 1: Parameter: N

Description: Annual number of 'Hass' avocado imported from Mexico.

Units:

$$\frac{\text{Avocados}}{\text{Year}}$$

Evidence on N:

1. Historical records of Hass avocado importations from Mexico are documented by APHIS in the Federal Register (Vol. 66, No. 135, p 36896-7), and summarized in table 1.

Table 1. Estimated number of Mexican 'Hass' avocado fruit entering the United States*

Season	Shipments	Boxes	Fruit
1997/1998	347	537,850	25,816,800
1998/1999	560	868,000	41,664,000
1999/2000	669	1,036,950	49,773,600
2000/2001	576	895,900	42,854,400
2001/2002	-	-	101,596,348

*Source: Federal Register Vol. 66, No. 135, p 36896-7;
2001/2002 values from J. G. Vila (USDA-APHIS-PPQ)

2. In 1997 'Hass' avocados were allowed to be shipped, from Michoacán, Mexico, to 19 states and the District of Columbia, and the allowable shipping season was November 15 to February 15.
3. Since November 2001, 'Hass' avocados have been allowed to be shipped to 31 states and the District of Columbia, and the allowable shipping season is October 15 to April 15 (7CFR§319.56-2ff)
4. It is proposed that avocados be allowed into all 50 states, with no seasonal restrictions.
5. 27,000 metric tons were imported from Mexico in 2002 (U.S. Department of Commerce, Bureau of the Census, 2002).
6. In 1994 there is 23,500 hectares of avocados in Michoacán, Mexico, that are certified and producing avocados for export to the whole world.
7. The Hass avocado yield in Michoacán, Mexico, is 9 metric tons per hectare.
8. There is an annual increase in the certified growing area of 15% per year. The increase is expected to extend over the next five years.
9. On average, there are 48 avocados per 25 pound box imported from Mexico.
10. 55,336,757 pounds of Hass avocados were imported from Mexico into the Northeast, East Central, and West Central regions during October 15, 2002 - April 15, 2003 (Mexican Hass imports, U.S. Department of Commerce, Bureau of the Census)
11. Based on a per capita consumption rate of 0.381 pounds per person, the quantity of Hass avocados that would be imported from Mexico, under year round consumption in all states is 219,160,210 and is presented in Table 2.

Table 2. Quantity of Hass avocados that would be imported from Mexico, (assuming year-round consumption in all states equal to the rate of per capita consumption of Hass avocados from Mexico in the Northeast, East Central, and West Central regions, October 15, 2002 - April 15, 2003)

		Hass avocado imports from Mexico, Oct 15, 2002 to Apr 15, 2003	Per Capita Consumption in the NE, EC, and WC Regions, Oct 15 - Apr 15	Hass Avocado Imports from Mexico, Assuming Average per Capita Consumption Year-round of 0.76 Pounds
Region ¹	2002 Population	pounds	pounds per capita	pounds
North East	70,158,899			
East Central	49,765,488			
West Central	25,383,994			
NE, EC, WC Regions	145,308,381	55,336,757	0.381	

Southeast	58,049,092
Southwest	27,128,666
Pacific	57,882,559
SE, SW, Pacific Regions	143,060,317

United States	288,368,698			219,160,210
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Source: 2002 population and Mexican Hass imports, U.S. Department of Commerce, Bureau of the Census.

¹Regions are according to California's Avocado Marketing Research and Information Center (AMRIC). Pacific: AK, AZ, CA, HI, ID, NV, OR, UT, WA; Southwest: NM, OK, TX; Southeast: AL, AR, FL, GA, LA, MS, NC, SC, TN; Northeast: CT, DC, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT, VA, WV; East Central: IL, IN, KY, MI, OH, WI; West Central: CO, IA, KS, MN, MO, MT, NE, ND, SD, WY.

Evaluation:

The amount of avocados to be imported from Mexico will increase at least proportionately to:

- a) the increased number of states that imports are allowed into (50 vs 31), and
- b) the increased time frame in which importation will occur (October to October vs October to April, 6 months vs 12 months)

The annual amount of avocados imported from Mexico will also depend on the potential increased production of avocados in Mexico into the future.

The quantity of imported avocados, N, is determined based on two import ranges, one nested within the other. The broader range represents amounts that could be imported, without reference to market expectations. Hass avocado imports from Mexico in 2002 serve as a lower bound for this range, and potential imports, based on expected total production in certified orchards after five years, is the upper bound. Within this first range, a second narrower range represents amounts that Mexico's exporters would expect to send to the United States in the next several years, if shipments to all states year-round were allowed. A hyperparameter consisting of uniform distribution nested within a Pert distribution was used to define the distribution for the annual number of avocados imported from Mexico.

APHIS estimates that between 114 million and 1.8 billion ‘Hass’ avocados will be imported from Mexico annually under the expanded distribution scheme. The most likely value ranges from 423 million to 635 million. This estimate is based on an assessment of the potential quantity of imported ‘Hass’ avocados from Mexico. This estimate is five to seven times the amount imported in the 2001/2002 season.

The probability distribution for the number of avocados imported is represented by a hyperparameter, N, which is actually a distribution within a distribution. The main distribution is a pert distribution defined by minimum, most likely, and maximum values. The most likely parameter of the pert distribution is a uniform distribution. All values between the minimum and maximum values of the uniform distribution have an equal likelihood of occurrence.

The pert distribution is represented by the following equation:

$$N = \text{RiskPert}(114 \text{ million}, \text{ML}, 1.8 \text{ billion})$$

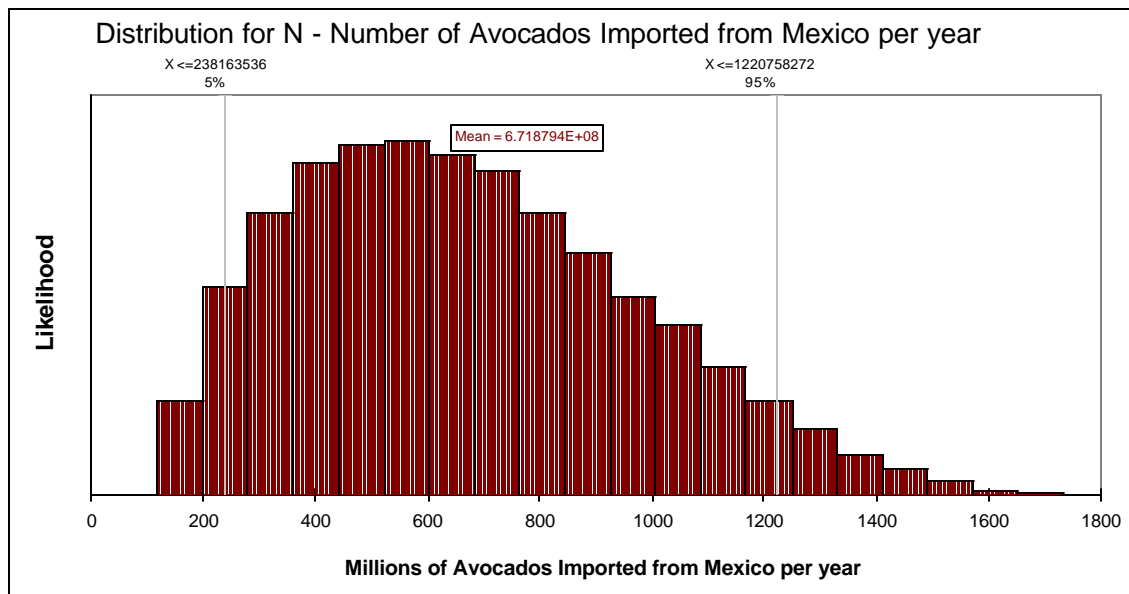
The most likely (ML) parameter of the pert distribution is a uniform distribution represented by the following equation:

$$\text{ML} = \text{RiskUniform}(423 \text{ million}, 635 \text{ million})$$

This hyper parameter, N, is presented in Figure 2., and the derivation of the argument values is presented following.

Figure 2. Distribution for the annual number of ‘Hass’ avocados imported into the US

(N = RiskPert(114 million , ML, 1.8 billion)
(ML = RiskUniform(423 million , 635 million)



Derivation of the minimum, maximum and most likely values of the distribution for N:

To help in conversions: There are an average of 48 avocados per 25pound box (Thus 1.92 avocados per pound). 1 Metric Ton = 2,205 pounds = 4,233 Avocados.

Minimum value of N: The lower bound of the broader range is 27,000 metric tons per year, the quantity of Hass avocados imported from Mexico in 2002 (U.S. Department of Commerce, Bureau of the Census, 2002). This equates to **114,286,464** avocados per year.

Maximum value of N: The upper bound of this range is 425,402 metric tons per year. Derivation of this quantity is based on the expected total production in certified areas in 2004. This is calculated by determining the total production in tons in 2004: 211,500 metric tons (23,500 hectares and 9 metric tons per hectare). An annual rate of increase in the certified area of 15 percent over five years, based on industry expectations necessitates multiplying the 211,500 metric tons by the compounded increase over five years ($2.0114 = \{1+0.15\}^5$), yields the 425,402 metric tons.

i	Total Production in 2004 (Hectares)	23,500		
j	Yield (Metric Tons per Hectare)	9		
k	Annual Percent Increase	0.15		
L	Number of years of increase	5		
c	Maximum	425,402	937,841,349	1,800,655,390

$C = (i*j)*(1+k)^L$

This upper bound assumes that all production from all certified orchards would be exported to the United States. It is unlikely that the actual number of avocados imported would exceed this level because the upper bounds (425,402 metric tons) exceeds the U.S. supply of avocados of all varieties from all sources, domestic and foreign, in 2002. The upper bounds (425,402 metric tons) equates to **1,800,655,390** avocados.

Most Likely Value of N: The second, more-narrow range has lower and upper bounds of 100,000 metric tons and 150,000 metric tons, respectively. The lower bound is based on per capita sales of Mexican Hass avocados in those states where they are currently allowed to be imported, October 15 to April 15, namely, 0.38 pounds per person for the six-month period (Table 2).

When this rate of consumption is extrapolated to all states year-round, the total quantity is about 219 million pounds, or roughly 100,000 metric tons per year. The upper bound, 150,000 tons per year, is based on the maximum quantity that the Mexican avocado industry expects to export to the United States for the foreseeable future. Converting the Tons per year to avocados per year yields a most likely value with a minimum and maximum of 423,283,200 and 634,924,800. A uniform distribution was used to represent the most likely value as:

RiskUniform(**423283200** , **634924800**)

Parameter Estimate Node 2: Parameter: *P1*

Description: Fraction/Proportion of Avocados reaching the UNITED STATES Infested.

Units:

Infested Avocados

Avocado

Evidence on *P1*:

P1-1. Seed weevils (*Conotrachelus aguacatae*, *Conotrachelus perseae*, and *Heilipus lauri*) and seed moths (*Stenoma catenifer*) have never been found in foliage and tree surveys in Michoacan, Mexico. In four years of surveys, the only pest detected via survey in Michoacan, Mexico is the stem weevil (*Copturus aguacatae*). Tables 3 & 4 contain data obtained from surveys in Michoacan, Mexico.

Table 3 - Foliage Surveys in Avocado Orchards in Michoacán, Mexico
(Proposed orchards to be included in the Hass avocado export program to the US)

Year	Number of Orchards	Number of Orchards Positive				
		Stem Weevil <i>Copturus aguacatae</i>	Seed Weevil <i>Heilipus lauri</i>	Seed Moth <i>Stenoma catenifer</i>	Seed Weevils <i>Conotrachelus aguacatae</i> & <i>C. perseae</i>	Fruit Flies <i>Anastrepha</i> spp. & <i>Ceratitidis capitata</i>
1997	61	0	0	0	0	0
1998	244	0	0	0	0	0
1999	500	3	0	0	0	0
2000	790	0	0	0	0	0
2001	996	1	0	0	0	0
2002	1,469	3	0	0	0	0
Total	4,060	7	0	0	0	0

Table 4 – Wild and Backyard Tree Surveys in Michoacán, Mexico

Year	No. of backyards	No. of wild trees surveyed	Number of Sites Positive				
			Stem Weevil <i>Copturus aguacatae</i>	Seed Weevil <i>Heilipus lauri</i>	Seed Moth <i>Stenoma catenifer</i>	Seed Weevils <i>Conotrachelus aguacatae</i> & <i>C. perseae</i>	Fruit Flies <i>Anastrepha</i> spp. & <i>Ceratitidis capitata</i>
1997	42	200	0	0	0	0	0
1998		107	19	0	0	0	0
1999	31	379	37	0	0	0	0
2000	54	270	25	0	0	0	0
2001	54	191	24	0	0	0	0
2002	398	762	145	0	0	0	0
Total	661	1,909	250	0	0	0	0

Source - USDA, APHIS, International Services. – NAR, 2003- Uruapan, Mich.

- P1-2. None of the orchards that were positive for Stem Weevil were permitted to export avocados to the US. They were removed from certification and the export program for the shipping season. (7CFR§319.56-2ff(e)(2) p. 331)
- P1-3. To date, more than ten million fruit have been cut as part of the avocado export program, and none of the five quarantine pests have been detected as shown in Table 5.

Table 5. Fruit sampled for seed weevils, stem weevil, seed moth, and fruit flies*

Season	Field Samples	Packing house	Border Inspection	Season Total	Quarantine Pests Detected
1997/1998	1,155,305	417,900	10,410	1,583,615	0
1998/1999	1,121,471	203,250	16,860	1,341,581	0
1999/2000	952,423	166,650	20,070	1,139,143	0
2000/2001	1,209,814	172,800	17,280	1,399,894	0
2001/2002	1,616,456	347,475	41,250	2,005,181	0
2002/2003	2,749,876	141,558	11,880	2,903,314	0
Subtotal	8,805,345	1,449,633	117,750	10,372,728	0

*Source: Federal Register Vol. 66, No. 135, p 36896-7 and Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion, Mexico. The table was update with numbers from the 2001/2002 and 2002/2003 shipping seasons.

Evaluation:

Examination of the survey data presented in tables 3 & 4 can lead one to conclude that seed weevils and seed moths do not exist in Michoacan, Mexico. However, APHIS is uncertain whether the lack of detection of these pests is due to pest absence, or is due to below-detectable-levels of pest prevalence. For purposes of this risk assessment, APHIS has assumed the latter.

According to evidence P1-3, none of the orchards that were positive for Stem Weevil (Table 3 & 4) were permitted to export avocados to the US. They were removed from the export program. The orchards that remained in the export program have been assumed to have stem weevils at below-detectable-levels of prevalence.

Examination of the sampling data for the six import seasons, in Table 5, indicates that a total of 10,372,728 avocados were sampled, and no quarantine pests were found.

The goal is to estimate the undetectable prevalence of pest infestation in the avocados that are imported into the United States.

The sampling data has been translated into the language of probability as follows:

- The sampling procedure is modeled as a binomial process where:
 - an avocado is either infested, or not infested, and
 - an infested avocado, when sampled and cut, is determined to be either infested or not infested. Sensitivity is a measure of likelihood that an infested avocado will be positively identified.
 - This likelihood of successful identification is the product of the prevalence of infestation and the sensitivity of the test, and does not change from trial to trial.
- The three parameters that characterize a binomial process are:
 - n, the number of trials
 - p, the probability of success on one trial
 - x, the number of successes in n trials
- Based on the sampling data (Table 5) the values of these three parameters are:
 - n, number of binomial trials, is 10,372,728
 - x, the number of successful trials (detections), is 0
 - p, the probability of success on one trial, x, is unknown. This probability of success is the product of the prevalence and the sensitivity. It is what we desire to estimate.
- **When n and x are known, as is the case in hand, the question that can be answered is:**
 - What is the probability of success on a single trial if there have been x detections in n observations?
 - The RiskBeta @Risk function can be used iteratively to develop a Beta probability distribution for the probability of success, p, as follows:

$$p = \text{RiskBeta}(x+1, n-x+1)$$

Because n is greater 7,000,000 the RiskBeta function in @Risk doesn't work. As a workaround we have made a transformation in the sample size, n as follows:

When the sensitivity of inspection is 100%, one needs half the sample size as one needs when the sensitivity is 50% to detect a given prevalence of infestation.

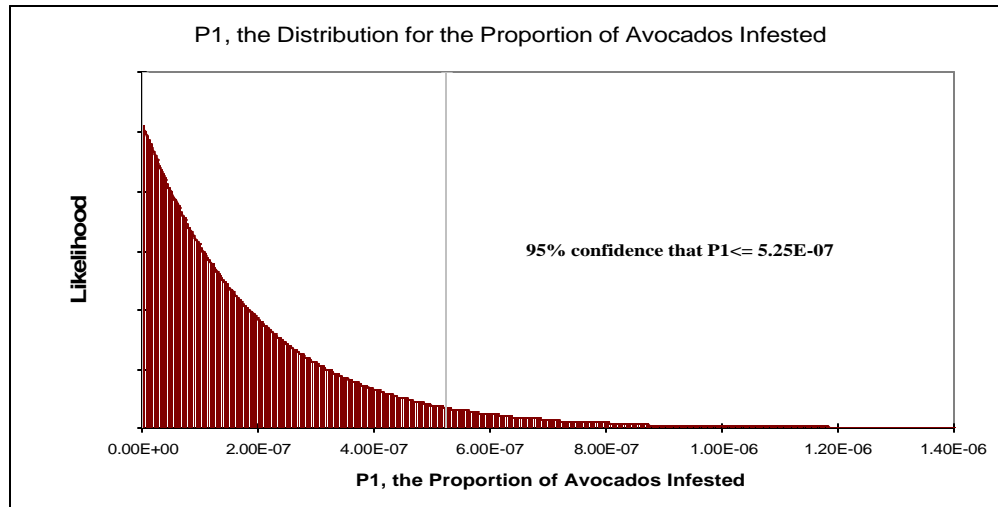
Therefore, sampling 10,372,728 avocados with a 50% sensitivity of inspection is equivalent to sampling 5,186,364 avocados with 100% sensitivity of inspection. This sample size works with the RiskBeta function.

APHIS has used the @Risk, RiskBeta function to generate the probability distribution for the proportion of infested avocados, P1. P1 is represented by the equation:

$$P1 = \text{RiskBeta}(x+1, n-x+1), \text{ where } x=0 \text{ and } n = 5,186,364$$

The resulting distribution is represented in figure 3.

Figure 3. Probability Distribution for P1, the Proportion of Infested Avocados



There is 95% confidence that the proportion of infested avocados is less or equal to 5.25×10^{-7} .
The most likely proportion of infested avocados is zero (0).

Parameter Estimate Node 3: Parameter: P2

Description: P2 is the proportion of infested avocados entering susceptible areas.

,

Units:

Infested Avocados entering susceptible area

Infested Avocado

Two quantitative determinations were performed for P2 as follows:

3. **For the Avocado Pests** (seed moth, stem weevil and three seed weevils), the susceptible areas are those in which the avocado host exists (avocado growing areas).
4. **For Fruit Flies**, since fruit flies can infest other fruit aside from Avocados, it was necessary to consider that the susceptible area to fruit fly infestation is the whole of plant hardiness zones 9-11.

Evidence:

P2-1. Table 6 presents the U.S. per capita consumption of avocados by region

P2-2. Table 7 presents the population in U.S. counties that grow avocados, the number of avocado farms in those counties, and the derived population of the county living in the proportionate area of the farms, and the derived population of the county living in the proportionate area of the farms with a one mile radius buffer around them.

In the evaluation of P2 the following important factors were considered:

- An assumption is made that infested avocados are homogeneously mixed in the total avocado population entering the U.S. from Mexico.
- Based on this assumption, the proportion of infested avocados entering susceptible areas is equivalent to the proportion of avocados entering susceptible areas.
- The number of avocados entering an area is based solely on the number of avocados consumed in an area.
- The number consumed in an area is dependent on the population in the area and the percapita consumption of the population

Therefore, the proportion of infested avocados entering an area is dependent on the population in the area, the percapita consumption of the population, and the total avocado consumption in the U.S. and can be determined as:

$$P2 = \frac{\text{Population in susceptible area} \times \text{Per Capita consumption of population}}{\text{Total avocado consumption in US}}$$

Table 6 - Approximate U.S. per Capita Consumption of Avocados, by Region, 2002

	2002	California Hass and non-Hass Avocado	Florida Avocado	Hass Avocado Imports from	Avocado Imports other than from		Consumption
<u>Region</u> ¹	<u>Population</u> ²	<u>Shipments</u> ³	<u>Shipments</u> ⁴	<u>Mexico</u> ⁵	<u>Mexico</u> ⁶	<u>Total Supply</u>	<u>per Capita</u>
-----pounds-----							
Pacific	57,882,559	196,496,750	3,206,256		92,343,798	292,046,803	5.0
Southwest	27,128,666	73,805,625	1,502,723		34,811,376	110,119,723	4.1
Southeast	58,049,092	33,883,650	27,517,768		27,341,565	88,742,983	1.5
Northeast	70,158,899	29,050,850	16,510,661	28,386,814	20,442,967	94,391,291	1.3
East Central	49,765,488	28,694,950	11,007,107	20,135,487	17,947,764	77,785,309	1.6
West Central	25,383,994	19,513,050	1,406,081	10,270,553	9,630,738	40,820,423	1.6
United States	288,368,698	381,444,875	61,150,595	58,792,854	202,518,207	703,906,532	2.4

Sources:

¹ Regions are according to California's Avocado Marketing Research and Information Center (AMRIC). Pacific: AK, AZ, CA, HI, ID, NV, OR, UT, WA; Southwest: NM, OK, TX; Southeast: AL, AR, FL, GA, LA, MS, NC, SC, TN; Northeast: CT, DC, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT, VA, WV; East Central: IL, IN, KY, MI, OH, WI; West Central: CO, IA, KS, MN, MO, MT, NE, ND, SD, WY.

²U.S. Department of Commerce, Bureau of the Census.

³AMRIC. All major California avocado handlers participate in the AMRIC system, representing about 95 percent of all California avocado production.

⁴Florida Avocado Administrative Committee (USDA Marketing Order #915). Reported production in 2002: 1,111,829 bushels, with each bushel 55 pounds. Distribution among regions based on personal communications with AMS and Florida Agricultural Extension staff.

⁵Total Hass avocado imports from Mexico based on U.S. Census Bureau data; distributed among the Northeast, East Central, and West Central regions by population.

⁶Total avocado imports other than from Mexico based on U.S. Census Bureau data; distributed among the regions in the same proportion as the California shipments for imports from Chile, New Zealand, Ecuador, and Brazil, and in the same proportion as the Florida shipments for imports from the Dominican Republic and the Bahamas.

Table 7 - Population in susceptible areas of the U.S.

County		Number of Avocado Farms	County Population	County Area (miles ²)	Pop. in avocado growing areas	Pop. in avocado growing areas (w/buffer)
Los Angeles	CA	90	9,519,338	4,752	5,664	685,297
Madera	CA	3	123,109	2,153	5	652
Monterey	CA	6	401,762	3,771	20	2,430
Orange	CA	37	2,846,289	948	3,490	422,296
Riverside	CA	558	1,545,387	7,303	3,709	448,846
San Benito	CA	5	53,234	1,391	6	728
San Bernardino	CA	41	1,709,434	20,105	110	13,251
San Diego	CA	2,757	2,813,833	4,526	53,854	6,516,312
San Joaquin	CA	9	563,598	1,426	112	13,519
San Luis Obispo	CA	122	246,681	3,616	262	31,642
Santa Barbara	CA	393	399,347	3,789	1,301	157,451
Santa Clara	CA	5	1,682,585	1,304	203	24,525
Santa Cruz	CA	32	255,602	607	423	51,209
Tulare	CA	50	368,021	4,839	119	14,455
Ventura	CA	902	753,197	2,208	9,666	1,169,532
Hawaii	HI	1,007	148,677	5,087	925	111,885
Honolulu	HI	8	876,156	2,127	104	12,528
Kauai	HI	13	58,463	1,266	19	2,281
Maui	HI	29	128,094	2,399	49	5,887
Brevard	FL	12	476,230	1,557	115	13,953
Broward	FL	5	1,623,018	741,043	0	42
Collier	FL	3	251,377	2,305	10	1,244
Dade	FL	482	2,253,362	2,431	14,034	1,698,173
Hillsborough	FL	4	998,948	1,266	99	11,996
Palm Beach	FL	4	1,131,184	2,386	60	7,208
Cameron	TX	6	335,227	1,276	50	5,990
Hidalgo	TX	10	569,463	1,583	113	13,675

Number of avocado farms from NASS Census of Agriculture.

Population from U.S. Census.

Evaluation of P2

In calculating P2, it is necessary to a) determine the susceptible area, b) determine the population in the susceptible area, c) determine the percapita consumption of that population, and d) divide the product of the population and the percapita consumption by the total number of avocados from Mexico.

Evaluation of P2 for the other pathway pests, P2,

The proportion of avocados consumed in susceptible areas, is represented in the model as a distribution defined by minimum, most-likely, and maximum values.

The minimum proportion of avocados consumed in susceptible areas (avocado growing areas). The *minimum susceptible area* is the total area of commercial avocado orchards in the U.S.

The *minimum susceptible area* was calculated as follows:

For each avocado growing county in the U.S., the number of avocado farms was multiplied by the area of each avocado farm (assumed to be 0.0314 square miles or 0.1 mile in radius). The product (square miles in avocados) was divided by the square miles in the county to determine the proportion of the county in avocados.

The population in the *minimum susceptible area* was determined as follows:

The proportion of area growing avocados was multiplied by the county population to determine the population in susceptible areas (assuming the population is evenly distributed). The population in avocado growing areas of each county within the Pacific, Southwest, and Southeast regions was determined from the data in table 7 and the results are shown in Table 8.

The number of avocados consumed in the *minimum susceptible area*:

The percapita consumption of each region (from table 6) was multiplied by the population in the susceptible area in each region (Table 7) to yield the number of avocados consumed in the susceptible area in each region.

Table 8 - Minimum proportion of avocados consumed in avocado growing areas of the U.S.

Region	Population	Per Capita Consumption	Avocados
Pacific	80,039	5.05	403,837
Southwest	163	4.06	660
Southeast	14,319	1.53	21,890
Avocados consumed in susceptible regions			426,388
Avocados consumed in the U.S.			703,906,532
Proportion consumed in susceptible regions			0.0006

Population values taken from table 7, per capita consumption rates from table 6, and total avocados consumed in the U.S. from table 6.

Table 8 shows the calculation of the minimum proportion of avocados consumed in susceptible regions. The population in susceptible regions is multiplied by the per capita avocado consumption in each region to determine the avocados consumed in susceptible

areas. The total avocados consumed in avocados growing areas divided by the total avocados consumed in the U.S. is the *proportion of avocados consumed in susceptible areas* in the U.S.

The Most Likely proportion of avocados consumed in susceptible areas (avocado growing areas). The *most likely susceptible area* is the total area of commercial avocado orchards in the U.S. including a one-mile buffer zone around each orchard. This parameter was calculated in the same manner as the *minimum susceptible area* except for the inclusion of a one mile buffer zone for each avocado farm. The area of each avocado farm is assumed to be 3.8 square miles (1.1 mile radius for each farm).

Table 9 - Most likely proportion of avocados consumed in susceptible areas of the U.S.

Region	population in susceptible areas	per capita consumption	avocados consumed in susceptible areas
Pacific	9,552,143	5.3	50,626,357
Southwest	19,665	4.1	80,628
Southeast	1,732,614	1.5	2,598,921
Hawaii	132,581	2.5	331,452
Avocados consumed in growing areas			53,637,359
Avocados consumed in the U.S.			703,906,532
Proportion of avocados consumed in growing areas			0.076

Population values taken from table 7, per capita consumption rates from table 6, and total avocados consumed in the U.S. from table 6.

Table 9 shows the calculation of the most likely *proportion of avocados consumed in susceptible regions*. The population in susceptible areas is multiplied by the per capita avocado consumption in each region to determine the avocados consumed in susceptible areas. The total avocados consumed in susceptible areas divided by the total avocados consumed in the U.S. is the *proportion of avocados consumed in susceptible areas* in the U.S.

The Maximum proportion of avocados consumed in avocado growing areas

The *maximum susceptible area* is all of plant hardiness zones 9-11 in the U.S. Hardiness zones 9-11 includes portions of California, Arizona, Florida, Louisiana, Nevada, Oregon, and Texas plus all of Hawaii. It is possible for avocados to grow in this region, even though the actual growing area is substantially less. Table 10 shows the population in counties within plant hardiness zones 9-11.

Table 11 shows the calculation of the proportion of avocados consumed in plant hardiness zones 9-11. The population in plant hardiness zones 9-11 is multiplied by the per capita avocado consumption in each region to determine the avocados consumed. The total avocados consumed in this area, divided by the total avocados consumed in the U.S. is the *proportion of avocados consumed in plant hardiness zones 9-11* in the U.S.

Table 10 – Population of U.S. Counties in Plant Hardiness Zones 9-11

California	Pop.	California	Pop.	Texas	Pop.	Florida	Pop.
Alameda	1,443,741	Stanislaus	446,997	Aransas	22,695	Brevard	489,522
Amador	35,100	Sutter	78,930	Bee	32,314	Broward	1,668,560
Butte	203,171	Tehama	56,039	Brazoria	249,832	Charlotte	147,009
Calaveras	40,554	Touloumne	54,501	Brooks	7,683	Citrus	122,470
Contra Costa	948,816	Trinity	13,022	Cameron	344,782	Clay	147,542
Del Norte	27,507	Tulare	368,021	Chambers	26,859	Collier	265,769
El Dorado	156,299	Ventura	753,197	Dawson	14,838	DeSoto	32,438
Fresno	799,407	Yolo	168,660	Dimmit	10,170	Duval	792,434
Glenn	26,453	Yuba	60,219	Duval	12,996	Flagler	54,964
Humboldt	126,518			Fort Bend	381,200	Glades	10,750
Imperial	142,361	Louisiana		Frio	16,392	Hardee	26,759
Inyo	17,945	Ascension	79,873	Galveston	255,865	Hendry	36,562
Kern	661,645	Assumption	23,257	Harris	3,460,589	Hernando	135,751
Kings	129,461	Calcaseiu	182,842	Jackson	14,291	Highland	88,972
Lake	58,309	Cameron	9,805	Jefferson	249,640	Hillsborough	1,027,318
Los Angeles	9,519,338	Iberia	73,530	Jim Hogg	5,161	Indian River	116,488
Madera	123,109	Jefferson	451,459	Jim Wells	39,950	Lake	227,598
		Jefferson					
Marin	247,289	Davis	31,275	Kennedy	413	Lee	462,455
Mariposa	17,130	Lafayette	190,894	Kleberg	31,015	Manatee	274,523
Mendocino	86,265	LaFourche	90,273	LaSalle	5,849	Marion	267,889
Merced	210,554	Plaquemines	27,004	Hidalgo	590,285	Martin	130,313
Monterrey	401,762	San Martin	49,181	Liberty	72,620	Miami-Dade	2,289,683
Napa	124,279	St Bernard	49,181	Live Oak	12,177	Monroe	78,556
Nevada	92,033	St Charles	48,548	Matagorda	38,157	Okeechobee	36,385
Orange	2,846,289	St James	21,224	Maverick	48,259	Orange	923,311
		St John					
Placer	248,399	Baptist	43,798	McMullen	849	Osceola	181,932
Riverside	1,545,387	St Mary	52,833	Nueces	312,470	Palm Beach	1,165,049
Sacramento	1,223,499	Terre Bonne	105,123	Orange	84,582	Pasco	362,658
San Benito	53,234	Vermillion	53,661	Refugio	7,729	Pinellas	924,610
San Bernardino	1,709,434			San Patricio	67,120	Polk	492,751
San Diego	2,813,833	Arizona		Starr	54,671	Putnam	70,880
San Francisco	776,733	Mojave	161,788	Victoria	84,710	Sarasota	335,323
San Joachim	563,598	Yuma	164,942	Webb	201,292	Seminole	374,334
San Luis Obispo	246,681	Yavapai	175,507	Wharton	41,202	St Johns	131,684
San Mateo	707,161	Maricopa	3,194,798	Willacy	19,905	St Lucie	200,018
Santa Barbara	399,347	Pinal	188,846	Zapata	12,461	Sumpter	54,504
Santa Clara	1,682,585	Pima	863,049	Oregon		Volusia	454,581
Santa Cruz	255,602	Cochise	119,281	Tillamook	24,308		
Shasta	163,256	Santa Cruz	39,590	Lane	324,316	Nevada	
Siskiyou	44,301			Douglas	100,866	Clark	1,464,653
Solano	394,542			Coos	62,459		
Sonoma	458,614			Curry	21,118		
Population from U.S. Census. The table includes all counties in the U.S. in plant hardiness zones 9-11.							

Table 11. Estimating the proportion of avocados consumed in plant hardiness zones 9-11 in the U.S.

State	Population	Region population	per capita consumption	avocados consumed
California	32,297,468			
Hawaii	1,224,398			
Oregon	533,067			
Nevada	1,464,653			
Arizona	4,907,801			
Total for pacific region		40,427,387	5.0	203,976,627
Texas	6,831,023			
Total for southwest region		6,831,023	4.1	27,728,247
Florida	14,602,345			
Louisiana	1,583,761			
Total for southeast region		16,186,106	1.5	24,744,630
Avocados consumed in growing areas				256,449,505
Avocados consumed in the U.S.				703,906,532
Proportion of avocados consumed in growing areas				0.364
Population values taken from table 9, per capita consumption rates from table 5, and total avocados consumed in the U.S. from table 5				

Evaluation of P2 for fruit flies

The *fruit fly susceptible area* is all of plant hardiness zones 9-11 in the U.S. Hardiness zones 9-11 includes portions of California, Arizona, Florida, Louisiana, Nevada, Oregon, and Texas plus all of Hawaii.

Table 11 shows the calculation of the proportion of avocados consumed in the fruit fly susceptible regions. The population in plant hardiness zones 9-11 is multiplied by the per capita avocado consumption in each region to determine the number of avocados consumed. The total avocados consumed in the fruit fly susceptible area, divided by the total avocados consumed in the U.S. is the *proportion of avocados consumed in the fruit fly susceptible areas* in the U.S.

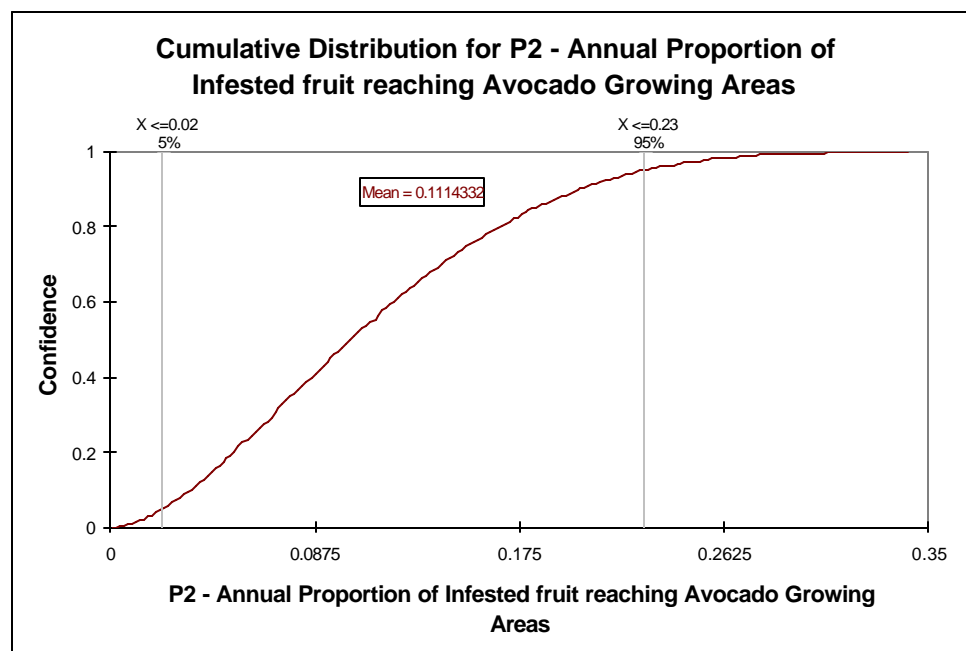
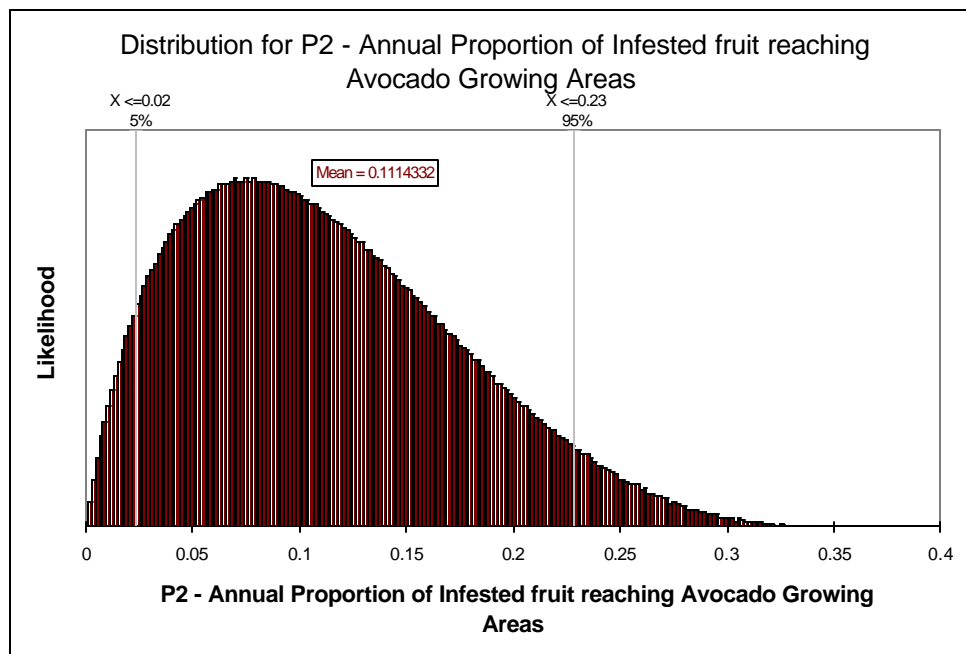
The proportion of avocados entering fruit fly susceptible areas, P2, is represented in the model as a point estimate, and has been determined to be 36.4% (Table 11)

There is no distribution for P2 for fruit fly susceptible areas

Distribution for **P2 for Avocado Pests:**

In this risk assessment an assumption has been made that the distribution of avocados in the United States depends solely on the relative consumption of avocados, and other market forces are not considered.

P2, is represented by a pert distribution that has a minimum value of 0.06%, a most likely value of 7.6% and a maximum value of 36.4%. The resulting probability distribution function (PDF) for P2 is presented below.



Parameter Estimate Node 4: P3

Description: P3 is the proportion of infested avocados that are discarded in susceptible areas.

Units:

Infested Avocados discarded in susceptible area

Infested Avocados entering susceptible area

One quantitative determination was performed for P3 as follows:

Evidence:

- P3-1. A maximum of 5% of fruit is routinely discarded into the environment. The other 95% is either eaten by consumers, thrown in the trash, or disposed of in such a way that any pests in it have no chance of establishing in a host population (APHIS, 2003d; Roberts *et al.*, 1998; Wearing *et al.*, 2001).

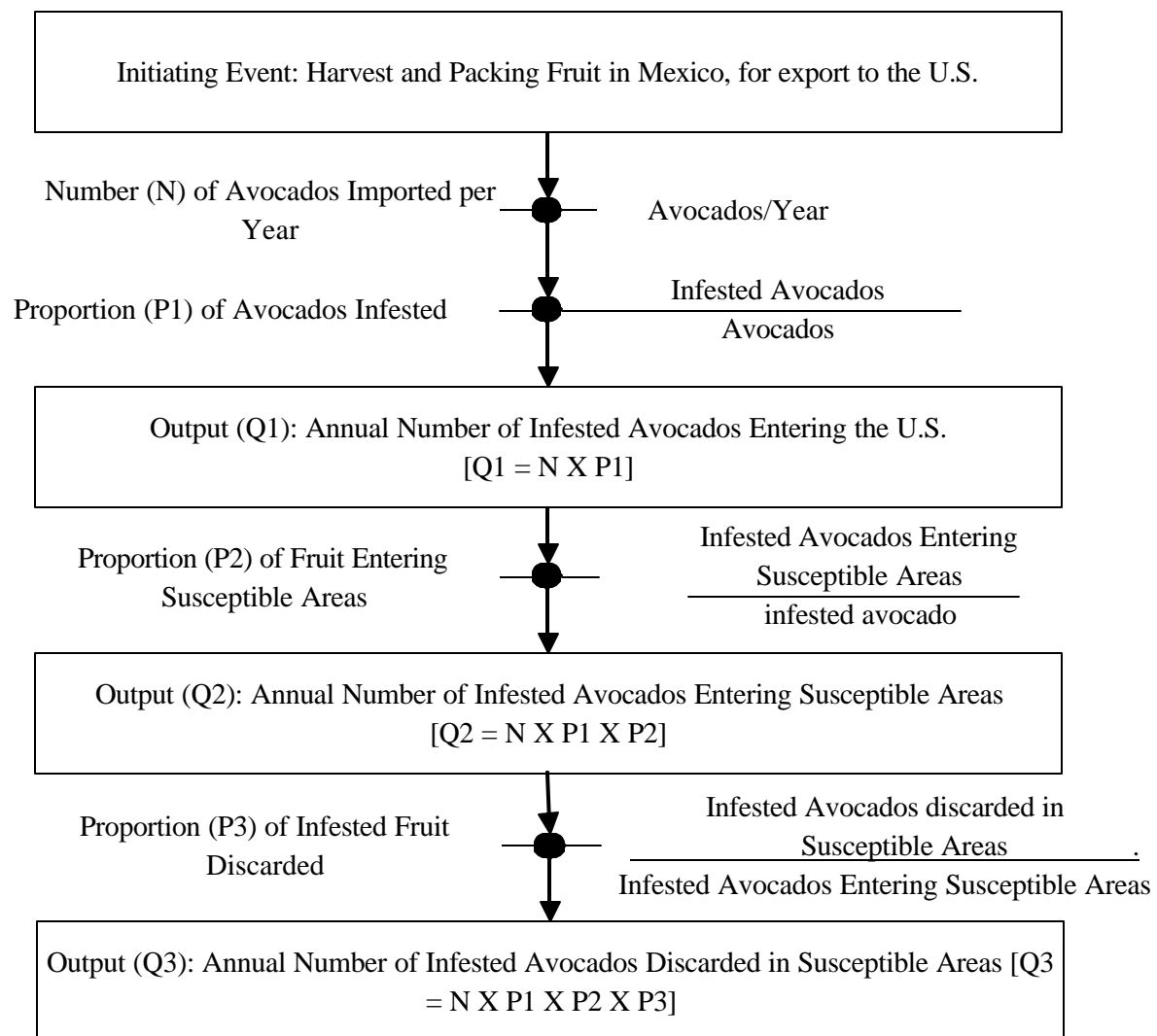
F. Mathematical Model: Performing Calculations

This quantitative risk assessment estimates the number of infested Mexican ‘Hass’ avocados that enter susceptible areas via the importation of avocados from Michoacán, Mexico.

The annual number of infested avocados entering susceptible areas in the United States is based on:

- a) N, the quantity of avocados imported from Mexico per year, and
- b) P1, the proportion of avocados that are still infested on importation to the United States (the pest infestation rate, as determined by inspection), and
- c) P2, the fraction of avocados likely to end up in susceptible areas.
- d) P3, the fraction of avocados likely to be discarded

The following risk pathway tree represents this.



As shown in the scenario tree, the annual number of infested avocados entering susceptible areas, Q2, is determined mathematically by taking the product of N, P1 and P2, as follows:

$$Q2 = N \times P1 \times P2$$

A dimensional analysis (Also shown in the scenario tree) yields the following units:

$$Q2 = \frac{\text{Avocados}}{\text{Year}} \times \frac{\text{Infested_Avocados}}{\text{Avocado}} \times \frac{\text{Infested_Avocados_reaching_Susceptible_Areas}}{\text{Infested_Avocado}}$$

Therefore:

$$Q2 = \frac{\text{Infested_Avocados_reaching_Susceptible_Areas}}{\text{Year}}$$

Similarly, the annual number of infested avocados discarded in susceptible areas, Q3, is determined mathematically by taking the product of N, P1, P2 and P3, as follows:

$$Q3 = N \times P1 \times P2 \times P3 \equiv Q2 \times P3$$

A dimensional analysis (Also shown in the scenario tree) yields the following units:

$$Q3 = \frac{\text{Infested_Avocados_reaching_Susceptible_Areas}}{\text{Year}} \times \frac{\text{Infested_Avocados_Discarded_in_Susceptible_Area}}{\text{Infested_Avocados_reaching_Susceptible_Areas}}$$

Therefore:

$$Q3 = \frac{\text{Infested_Avocados_Discarded_in_Susceptible_Area}}{\text{Year}}$$

Each of the parameters N, P1, P2 and P3 are defined by probability distributions that describe a range of possible values and their likelihood of occurrence.

In order to implement the multiplication of these distributions, APHIS has used the Monte Carlo simulation abilities of the @RISK (Palisade Corporation, Newfield, New York) software to run 20,000 iterations of this model, with a seed value of 100.

Following are the results.

Results

Between 114 million and 1.8 billion ‘Hass’ avocados will be imported each year from Mexico. Following is a summary of the results of conducting the twenty thousand MonteCarlo iterations of the risk assessment model using @Risk (Palisade Corporation, Newfield, New York) and Excel (Microsoft Corporation, Redmond, Washington).

A simulation of the proposed importation of Hass Avocados from Mexico, carried out with the appropriate systems mitigations and safeguards, has determined with a 95% confidence that:

- the most likely number of infested avocados reaching the United States each year is zero.
- the most likely number of infested avocados reaching susceptible areas in the United States each year is zero.
- The most likely number of infested avocados discarded in susceptible areas in the United States each year is zero

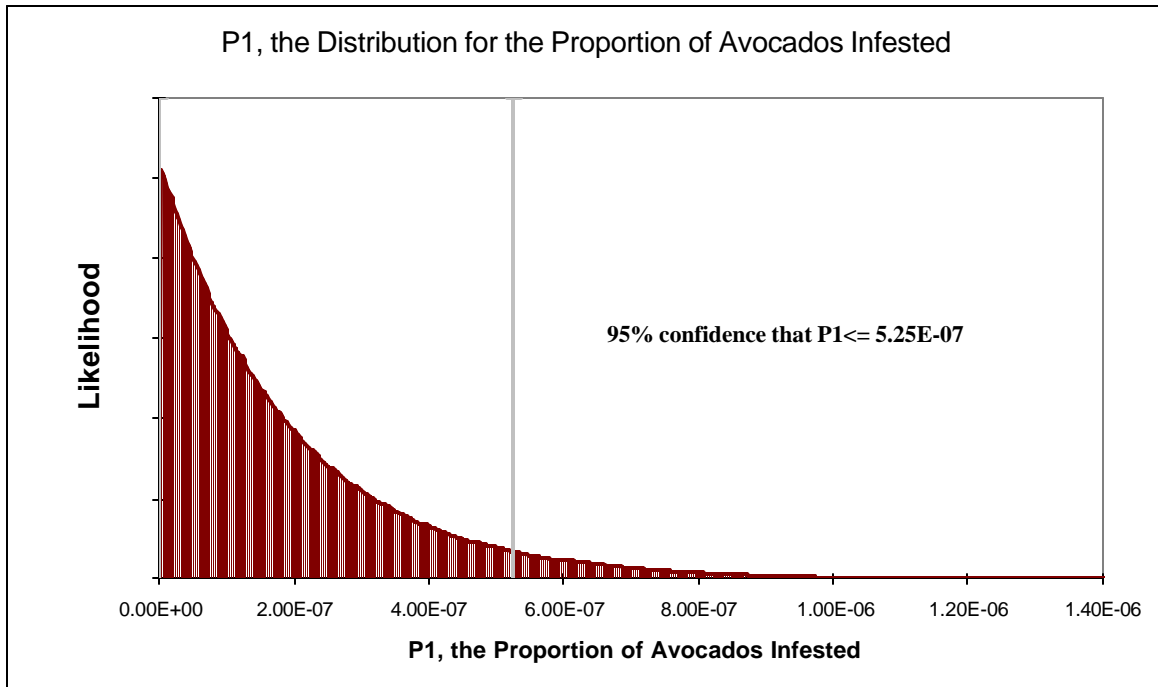
The simulation results also indicate with a 95% confidence that as a result of importing ‘Hass’ avocados from Mexico:

- The most likely number of infested avocados entering the United States each year is zero.
- The most likely number of infested avocados entering avocado growing counties in the United States each year is zero.
- Less than 387 infested avocados will enter the United States each year, estimated with 95% confidence.
- Less than 49 avocados infested with stem weevil, seed weevils and seed moth will enter avocado producing areas each year.
- less than 143 avocados infested with fruit flies will enter fruit fly susceptible areas each year.
- Less than 3 avocados infested with stem weevil, seed weevils and seed moth will be discarded in avocado producing areas each year.
- Less than 8 avocados infested with fruit flies will be discarded in fruit fly susceptible areas each year.

P1, Proportion of Avocados that are Infested

As determined by the sampling and fruit cutting data, the proportion of avocados infested with fruit flies is the same as the proportion of avocados infested with the seed weevils, stem weevils or seed moth. The probability distribution is presented below.

Probability Density Distribution

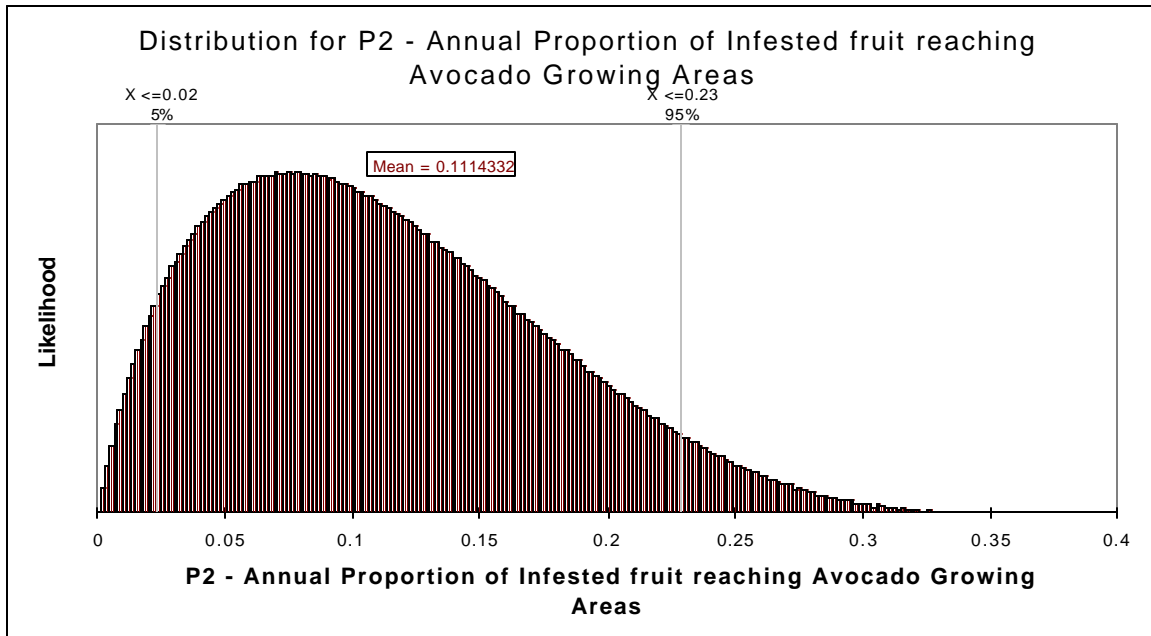


P2, Proportion of Infested Avocados entering Susceptible Areas

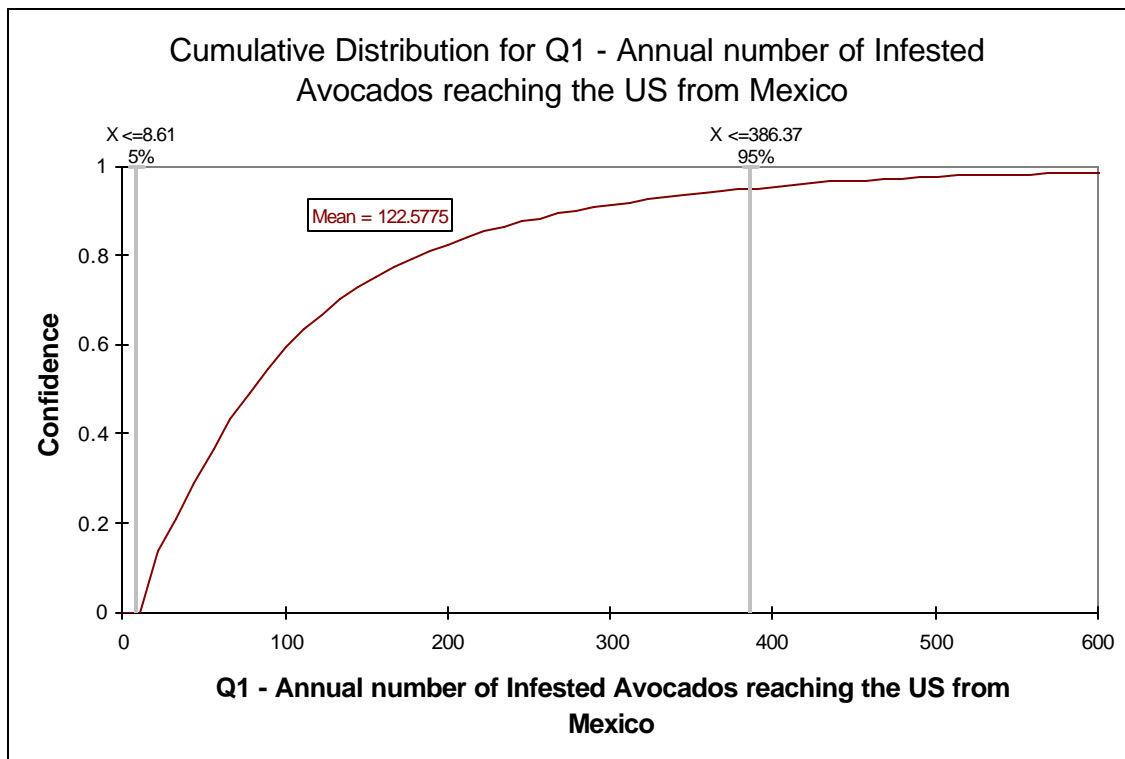
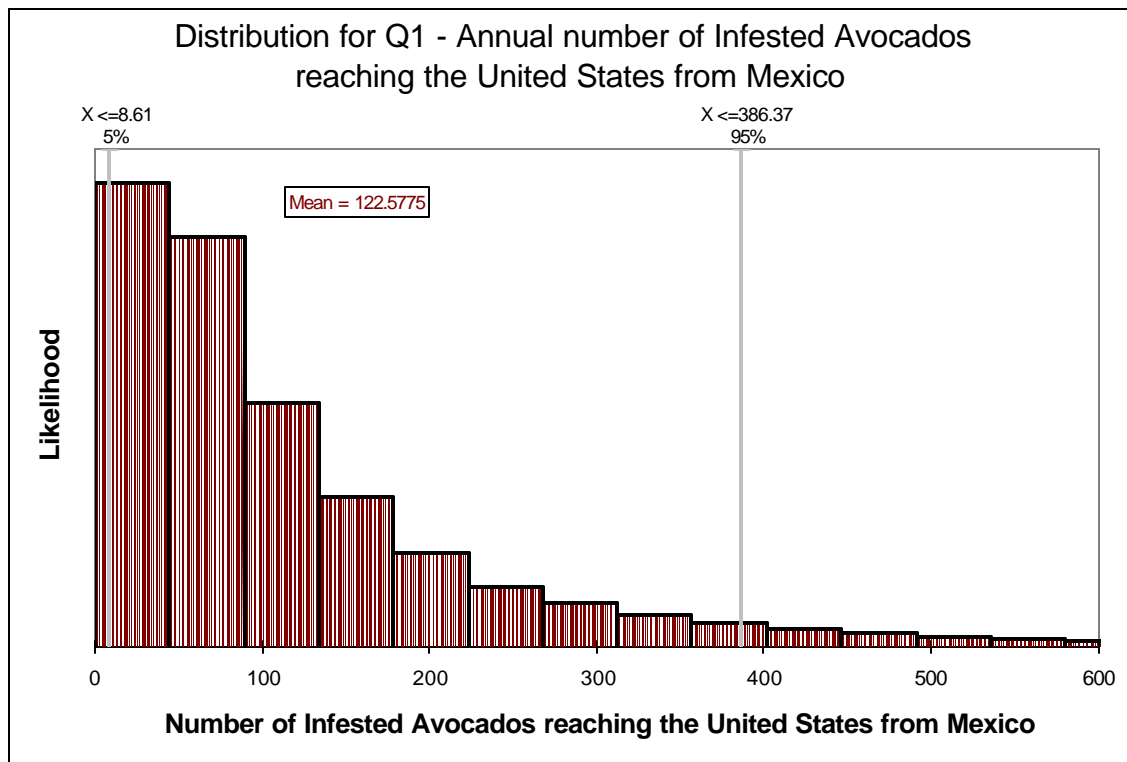
For the fruit fly: the annual proportion of infested avocados entering fruit fly susceptible areas is a point value of 36.4%

For the avocado pests: the annual proportion of infested avocados entering avocado growing areas is represented by the following distribution.

Probability Density Distribution

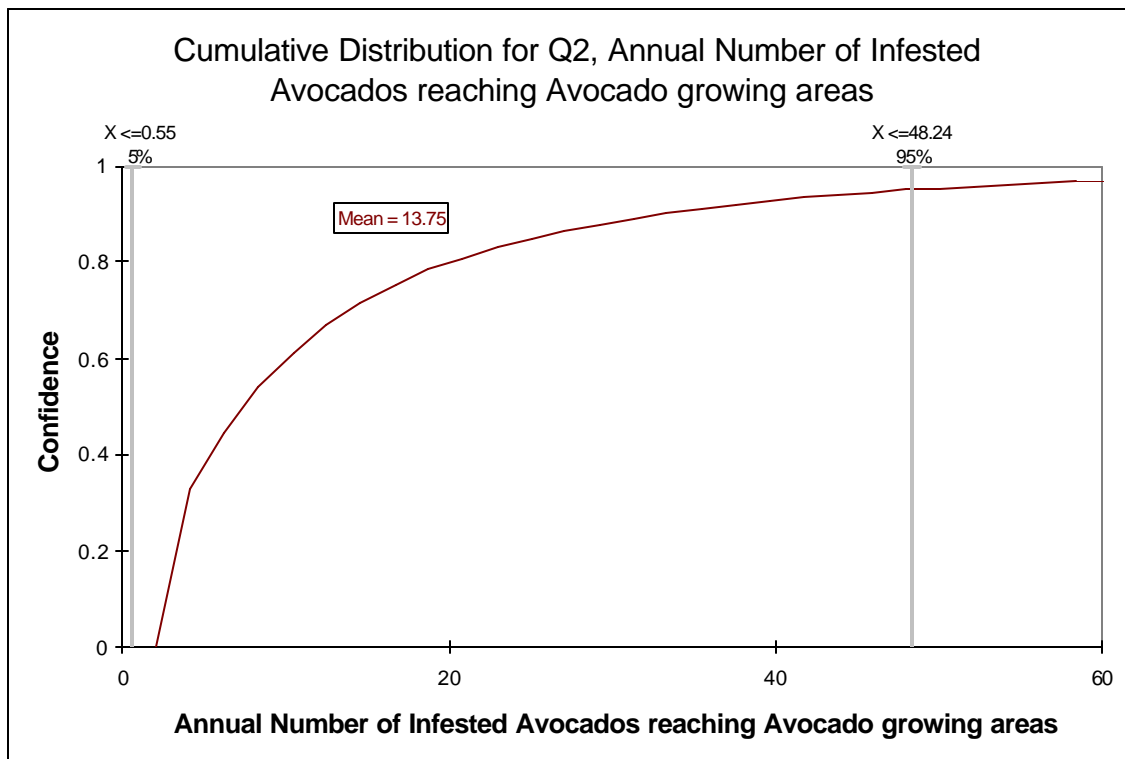
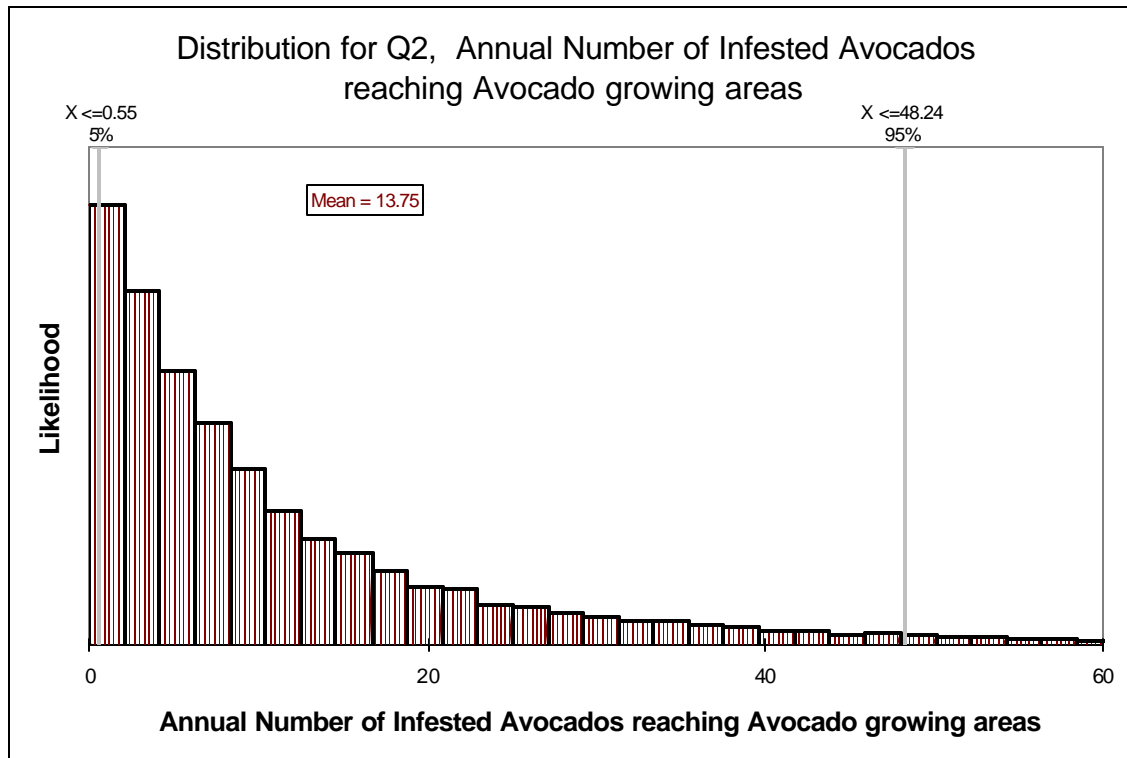


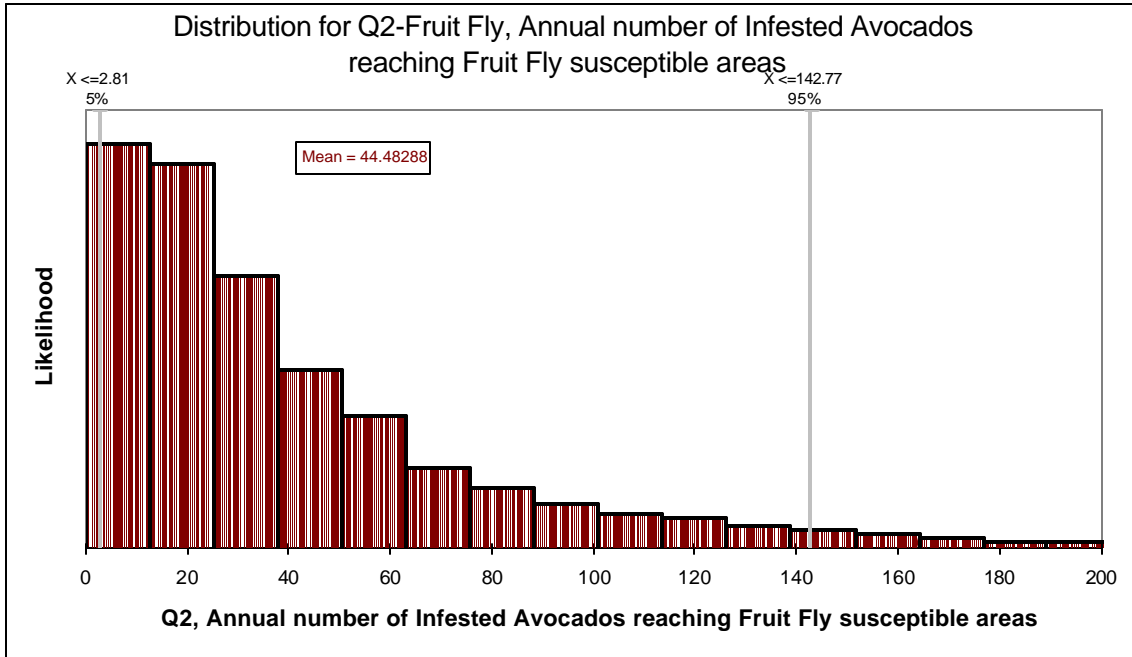
Q1, Annual number of Infested avocados reaching the US
Probability Density Distribution

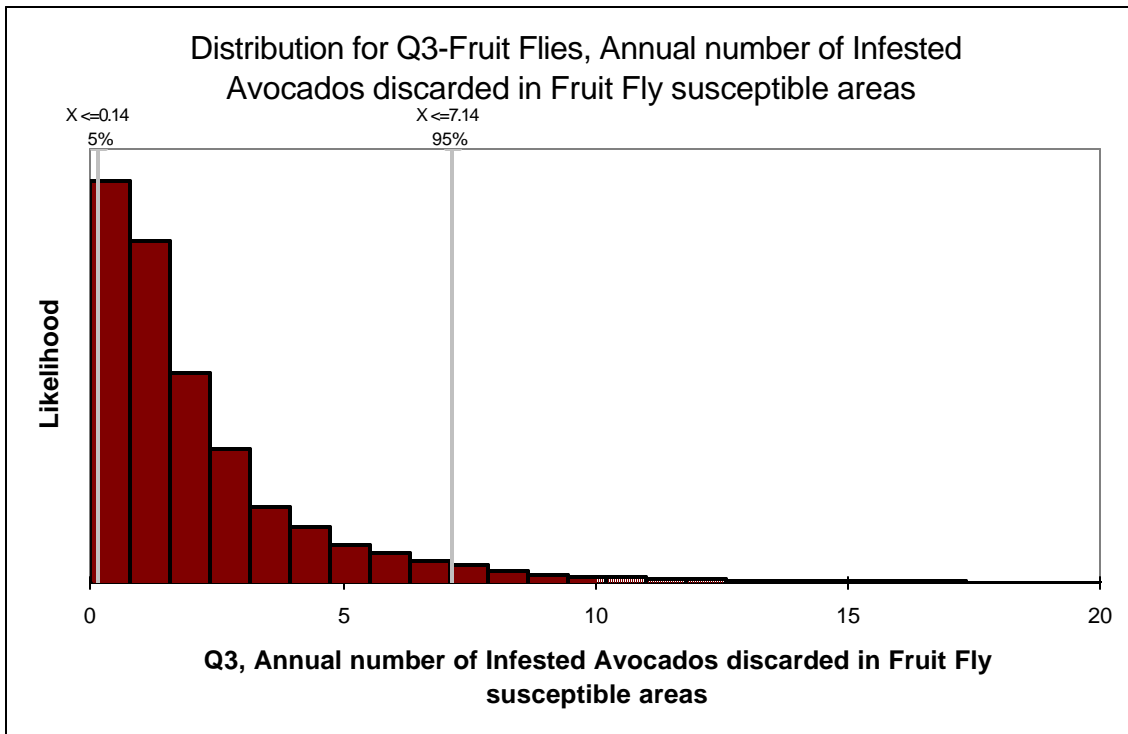
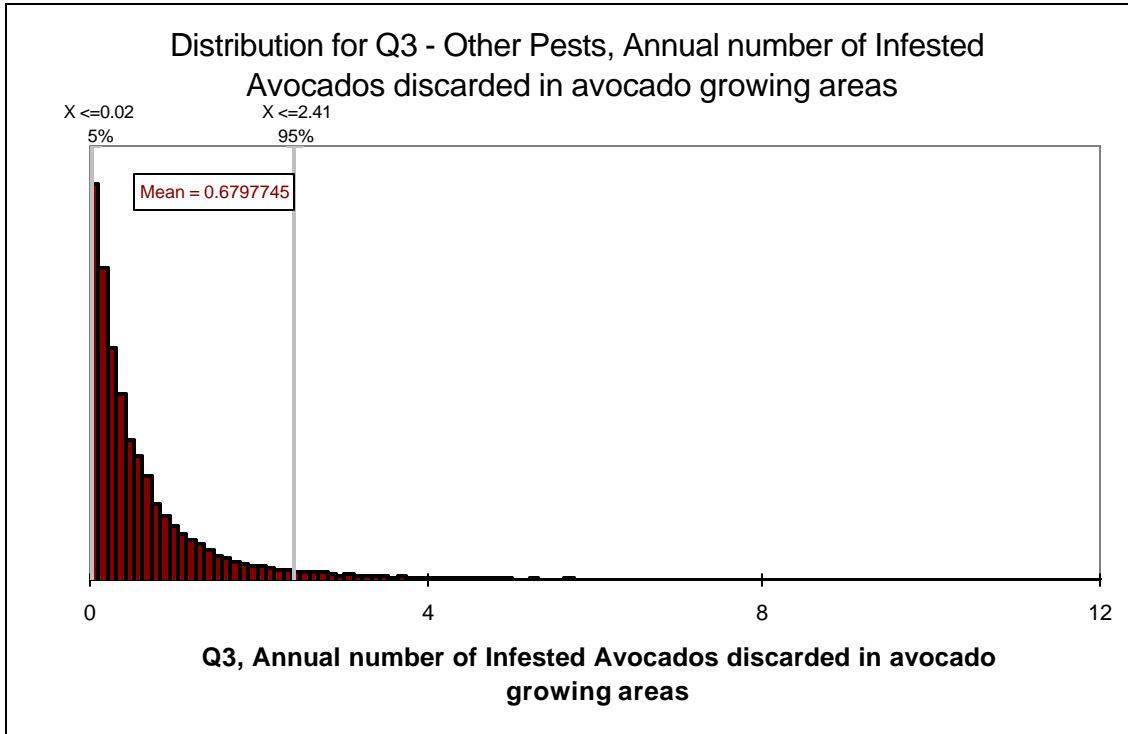


Q2, Annual number of Infested Avocados reaching susceptible areas

Probability Density Distribution

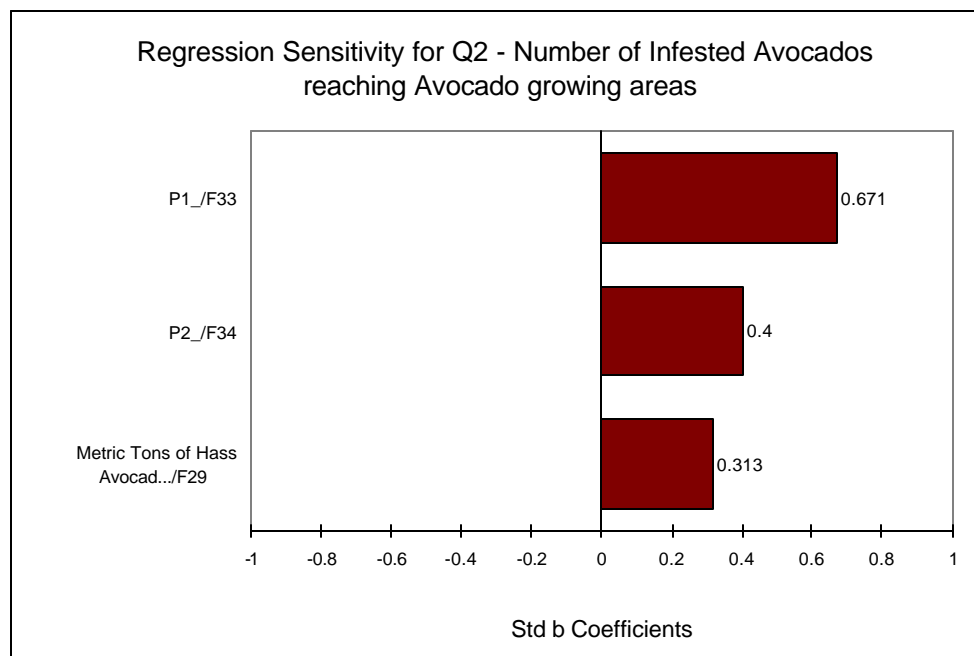
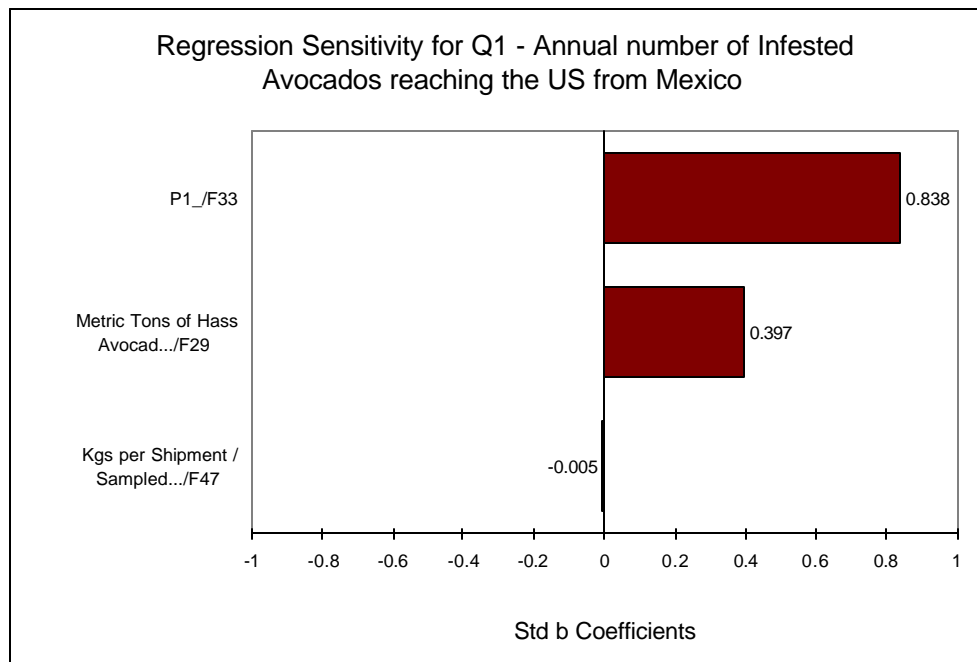






Sensitivity Analysis Results:

The following figures present the sensitivity analysis results.



Based on a sensitivity analysis it has been found that:

1. the number of infested avocados reaching the U.S., Q1, is most sensitive to the proportion of avocados in Mexico that are infested, P1.
2. the number of infested avocados reaching susceptible areas, Q2, is most sensitive to the proportion of avocados in Mexico that are infested, P1.

Appendix E – 7CFR§319.56-2ff

Administrative instructions governing the movement of ‘Hass’ avocados from Michoacán, Mexico to approved states.

Fresh ‘Hass’ variety avocados (*Persea americana*) may be imported from Michoacán, Mexico, into the United States for distribution in approved States only under a permit issued in accordance with § 319.56-4, and only under the following conditions:

(a) Shipping restrictions.

- (1) The avocados may be imported in commercial shipments only;
- (2) The avocados may be imported only between October 15 and April 15 of the following year; and
- (3) The avocados may be distributed only in the following States: Colorado, Connecticut, Delaware, the District of Columbia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Utah, Vermont, Virginia, West Virginia, Wisconsin, and Wyoming.

- (b) Trust fund agreement. The avocados may be imported only if the Mexican avocado industry association representing Mexican avocado growers, packers, and exporters has entered into a trust fund agreement with the Animal and Plant Health Inspection Service (APHIS) for that shipping season. That agreement requires the Mexican avocado industry association to pay in advance all estimated costs that APHIS expects to incur through its involvement in the trapping, survey, harvest, and packinghouse operations prescribed in paragraph (c) of this section. These costs will include administrative expenses incurred in conducting the services and all salaries (including overtime and the Federal share of employee benefits), travel expenses (including per diem expenses), and other incidental expenses incurred by the inspectors in performing these services. The agreement requires the Mexican avocado industry association to deposit a certified or cashier's check with APHIS for the amount of those costs, as estimated by APHIS. If the deposit is not sufficient to meet all costs incurred by APHIS, the agreement further requires the Mexican avocado industry association to deposit with APHIS a certified or cashier's check for the amount of the remaining costs, as determined by APHIS, before the services will be completed. After a final audit at the conclusion of each shipping season, any overpayment of funds would be returned to the Mexican avocado industry association or held on account until needed.

- (c) Safeguards in Mexico. The avocados must have been grown in the Mexican State of Michoacán in an orchard located in a municipality that meets the requirements of paragraph (c)(1) of this section. The orchard in which the avocados are grown must meet the requirements of paragraph (c)(2) of this section. The avocados must be packed for export to the United States in a packinghouse that meets the requirements of paragraph (c)(3) of this section. Sanidad Vegetal must provide an annual work plan to APHIS that details the activities that Sanidad Vegetal will, subject to APHIS' approval of the work plan, carry out to meet the requirements of this section; APHIS will be directly involved with Sanidad Vegetal in the monitoring and supervision of those activities. The personnel conducting the trapping and pest surveys must be hired, trained, and supervised by Sanidad Vegetal or by the Michoacán State delegate of the Secretaria de Agricultura, Ganaderia y Desarrollo Rural (SAGDR).

(1) Municipality requirements.

- (i) The municipality must be listed as an approved municipality in the annual work plan provided to APHIS by Sanidad Vegetal.
- (ii) The municipality must be surveyed at least annually and found to be free from the large avocado seed weevil *Heilipus lauri*, the avocado seed moth *Stenomoma catenifer*, and the small avocado seed weevils *Conotrachelus aguacatae* and *C. perseae*. The survey must cover at least 300 hectares in the municipality and include randomly selected portions of each registered orchard and areas with wild or backyard avocado trees. The survey must be conducted during the growing season and completed prior to the harvest of the avocados.
- (iii) Trapping must be conducted in the municipality for Mediterranean fruit fly (Medfly) (*Ceratitis capitata*) at the rate of 1 trap per 1 to 4 square miles. Any findings of Medfly must be reported to APHIS.

- (2) Orchard and grower requirements. The orchard and the grower must be registered with Sanidad Vegetal's avocado export program and must be listed as an approved orchard or an approved grower in the annual work plan provided to APHIS by Sanidad Vegetal. The operations of the orchard must meet the following conditions:

- (i) The orchard and all contiguous orchards and properties must be surveyed annually and found to be free from the avocado stem weevil *Copturus aguacatae*. The survey must be conducted during the growing season and completed prior to the harvest of the avocados.
 - (ii) Trapping must be conducted in the orchard for the fruit flies *Anastrepha ludens*, *A. serpentina*, and *A. striata* at the rate of one trap per 10 hectares. If one of those fruit flies is trapped, at least 10 additional traps must be deployed in a 50-hectare area immediately surrounding the trap in which the fruit fly was found. If within 30 days of the first finding any additional fruit flies are trapped within the 260-hectare area surrounding the first finding, malathion bait treatments must be applied in the affected orchard in order for the orchard to remain eligible to export avocados.
 - (iii) Avocado fruit that has fallen from the trees must be removed from the orchard at least once every 7 days and may not be included in field boxes of fruit to be packed for export.
 - (iv) Dead branches on avocado trees in the orchard must be pruned and removed from the orchard.
 - (v) Harvested avocados must be placed in field boxes or containers of field boxes that are marked to show the Sanidad Vegetal registration number of the orchard. The avocados must be moved from the orchard to the packinghouse within 3 hours of harvest or they must be protected from fruit fly infestation until moved.
 - (vi) The avocados must be protected from fruit fly infestation during their movement from the orchard to the packinghouse and must be accompanied by a field record indicating that the avocados originated from a certified orchard.
- (3) Packinghouse requirements. The packinghouse must be registered with Sanidad Vegetal's avocado export program and must be listed as an approved packinghouse in the annual work plan provided to APHIS by Sanidad Vegetal. The operations of the packinghouse must meet the following conditions:
- (i) During the time the packinghouse is used to prepare avocados for export to the United States, the packinghouse may accept fruit only from orchards certified by Sanidad Vegetal for participation in the avocado export program.
 - (ii) All openings to the outside must be covered by screening with openings of not more than 1.6 mm or by some other barrier that prevents insects from entering the packinghouse.
 - (iii) The packinghouse must have double doors at the entrance to the facility and at the interior entrance to the area where the avocados are packed.
 - (iv) Prior to the culling process, a sample of 300 avocados per shipment must be selected, cut, and inspected by Sanidad Vegetal and found free from pests.
 - (v) The identity of the avocados must be maintained from field boxes or containers to the shipping boxes so the avocados can be traced back to the orchard in which they were grown if pests are found at the packinghouse or the port of first arrival in the United States.
 - (vi) Prior to being packed in boxes, each avocado fruit must be cleaned of all stems, leaves, and other portions of plants and labeled with a sticker that bears the Sanidad Vegetal registration number of the packinghouse.
 - (vii) The avocados must be packed in clean, new boxes, or clean plastic reusable crates. The boxes or crates must be clearly marked with the identity of the grower, packinghouse, and exporter, and the statement "Not for distribution in AL, AK, AZ, AR, CA, FL, GA, HI, LA, MS, NV, NM, NC, OK, OR, SC, TN, TX, WA, Puerto Rico, and all other U.S. Territories."
 - (viii) The boxes must be placed in a refrigerated truck or refrigerated container and remain in that truck or container while in transit through Mexico to the port of first arrival in the United States. Prior to leaving the packinghouse, the truck or container must be secured by Sanidad Vegetal with a seal that will be broken when the truck or container is opened. Once sealed, the refrigerated truck or refrigerated container must remain unopened until it reaches the port of first arrival in the United States.
 - (ix) Any avocados that have not been packed or loaded into a refrigerated truck or refrigerated container by the end of the work day must be kept in the screened packing area.
- (d) Certification. All shipments of avocados must be accompanied by a phytosanitary certificate issued by Sanidad Vegetal certifying that the conditions specified in this section have been met.
- (e) Pest detection.
- (1) If any of the avocado seed pests *Heilipus lauri*, *Conotrachelus aguacatae*, *C. perseae*, or *Stenomoma catenifer* are

discovered in a municipality during an annual pest survey, orchard survey, packinghouse inspection, or other monitoring or inspection activity in the municipality, Sanidad Vegetal must immediately initiate an investigation and take measures to isolate and eradicate the pests. Sanidad Vegetal must also provide APHIS with information regarding the circumstances of the infestation and the pest risk mitigation measures taken. The municipality in which the pests are discovered will lose its pest-free certification and avocado exports from that municipality will be suspended until APHIS and Sanidad Vegetal agree that the pest eradication measures taken have been effective and that the pest risk within that municipality has been eliminated.

- (2) If Sanidad Vegetal discovers the stem weevil *Copturus aguacatae* in an orchard during an orchard survey or other monitoring or inspection activity in the orchard, Sanidad Vegetal must provide APHIS with information regarding the circumstances of the infestation and the pest risk mitigation measures taken. The orchard in which the pest was found will lose its export certification immediately and will be denied export certification for the entire shipping season of October 15 through April 15.
 - (3) If Sanidad Vegetal discovers the stem weevil *Copturus aguacatae* in fruit at a packinghouse, Sanidad Vegetal must investigate the origin of the infested fruit and provide APHIS with information regarding the circumstances of the infestation and the pest risk mitigation measures taken. The orchard where the infested fruit originated will lose its export certification immediately and will be denied export certification for the entire shipping season of October 15 through April 15.
- (f) Ports. The avocados may enter the United States at:
- (1) Any port located in a State specified in paragraph (a)(3) of this section;
 - (2) The ports of Galveston or Houston, TX, or the border ports of Nogales, AZ, or Brownsville, Eagle Pass, El Paso, Hidalgo, or Laredo, TX; or
 - (3) Other ports within that area of the United States specified in paragraph (g) of this section.
- (g) Shipping areas.
- (1) Except as explained below in paragraph (g)(3) for avocados that enter the United States at Nogales, AZ, avocados moved by truck or rail car may transit only that area of the United States bounded as follows:
 - (i) On the east and south by a line extending from Brownsville, TX, to Galveston, TX, to Kinder, LA, to Memphis, TN, to Knoxville, TN, following Interstate 40 to Raleigh, NC, and due east from Raleigh, and
 - (ii) On the west by following Interstate 10 North from El Paso, TX, to Las Cruces, NM, and north following Interstate 25 to the Colorado border, then west along Colorado and Utah's southern borders, then north along Utah's western border, then west along Idaho's southern border and north along Idaho's western border to the border with Canada.
 - (2) All cities on the boundary lines described in paragraph (g)(1) are included in this shipping area. If the avocados are moved by air, the aircraft may not land outside this shipping area.
 - (3) Avocados that enter the United States at Nogales, AZ, must be moved to Las Cruces, NM, by the route specified on the permit, and then must remain within the shipping area described above in this paragraph.
- (h) Shipping requirements. The avocados must be moved through the United States either by air or in a refrigerated truck or refrigerated rail car or in a refrigerated container on a truck or rail car. If the avocados are moved in a refrigerated container on a truck or rail car, an inspector must seal the container with a serially numbered seal at the port of first arrival in the United States. If the avocados are moved in a refrigerated truck or a refrigerated rail car, an inspector must seal the truck or rail car with a serially numbered seal at the port of first arrival in the United States. If the avocados are transferred to another vehicle or container in the United States, an inspector must be present to supervise the transfer and must apply a new serially numbered seal. The avocados must be moved through the United States under Customs bond.
- (i) Inspection. The avocados are subject to inspection by an inspector at the port of first arrival, at any stops in the United States en route to an approved State, and upon arrival at the terminal market in the approved States. At the port of first arrival, an inspector will sample and cut avocados from each shipment to detect pest infestation.
- (j) Repackaging. If any avocados are removed from their original shipping boxes and repackaged, the stickers required

by paragraph (c)(3)(vi) of this section may not be removed or obscured and the new boxes must be clearly marked with all the information required by paragraph (c)(3)(vii) of this section.

(k) Compliance agreements.

- (1) Any person, other than the permittee, who moves or distributes the avocados following their importation into the United States (i.e., a second-party or subsequent handler) must enter into a compliance agreement with APHIS. In the compliance agreement, the person must acknowledge, and agree to observe, the requirements of paragraph (a) and paragraphs (f) through (k) of this section. Compliance agreement forms are available, free of charge, from local offices of Plant Protection and Quarantine, which are listed in local telephone directories. A compliance agreement will not be required for an individual place of business that only offers the avocados for sale directly to consumers.
- (2) Before transferring the avocados to any person (i.e., a second-party handler) for movement or distribution, the permittee must confirm that the second-party handler has entered into a compliance agreement with APHIS as required by paragraph (k)(1) of this section. If the permittee transfers the avocados to a second-party handler who has not entered into a compliance agreement, APHIS may revoke the permittee's import permit for the remainder of the current shipping season.
- (3) Any second-party or subsequent handler who transfers the avocados to another person for movement or distribution must confirm that the person receiving the avocados has entered into a compliance agreement with APHIS as required by paragraph (k)(1) of this section. If the second-party or subsequent handler transfers the avocados to a person who has not entered into a compliance agreement, APHIS may revoke the handler's compliance agreement for the remainder of the current shipping season.
- (4) Action on repeat violators. APHIS may deny an application for an import permit from, or refuse to enter into a compliance agreement with, any person who has had his or her import permit or compliance agreement revoked under paragraph (k)(2) or (k)(3) of this section twice within any 5-year period.

(Approved by the Office of Management and Budget under control number 0579-0129)

[62 FR 5313, Feb. 5, 1997, as amended at 64 FR 68005, Dec. 6, 1999; 66 FR 55551, Nov. 1, 2001]

Appendix F – ARS Analysis of Aluja *et al* (In Press a) Fruit Fly Research

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United States Department of Agriculture
Research, Education, and Economics
Agricultural Research Service

February 12, 2004

SUBJECT: Hass Avocado

TO: Richard Dunkle, Deputy Administrator
Animal and Plant Health Inspection Service

FROM: Judith B. St. John 
Associate Deputy Administrator

This report summarizes the ARS review of the APHIS Hass avocado pest risk analysis. The review was conducted at the request of APHIS to provide comments on an APHIS pest risk analysis concerning a request from Mexico to expand Hass avocado importation into the United States (letter from Dr. Richard Dunkle, Deputy Administrator, PPQ, to Dr. Ken Vick, National Program Leader, ARS, dated September 4, 2003). During subsequent conversations with APHIS personnel in Raleigh, North Carolina, ARS noted that its expertise lay with the Mexican fruit fly part of this issue. Therefore, ARS' review focuses on the fruit fly research project (Aluja *et al*, in press) submitted by Mexico in support of their request for expanded Hass avocado importation. This study concluded Hass avocado was not a host for Mexican fruit fly and was central to the Mexican fruit fly component of the avocado pest risk analysis. The non-host designation essentially removed the fruit fly from the first draft of the APHIS pest risk analysis exercise.

This is, therefore, a review of the study submitted by Dr. Martin Aluja to APHIS on host status of Hass avocado relative to Mexican fruit fly in Mexico (Martin Aluja, Francisco Diaz-Fleischer, and Jose Arredondo. In press. Non-host status of commercial *Persea Americana* cultivar "Hass" to *Anastrepha ludens*, *A. oblique*, *A. serpentine*, and *A. striata* (Diptera: Tephritidae), *Journal Economic Entomology*). ARS also took into account other available pertinent information related to the avocado host status issue in forming its conclusions.

Two ARS scientists, Dr. Peter Follett, Hilo, Hawaii, and Dr. Robert Mangan, Weslaco, Texas, conducted the initial ARS review; both have considerable experience in host status issues including avocados. In particular, they are familiar with ARS work in the late 1980's and early 1990's establishing the host status of Sharwil avocados relative to fruit flies in Hawaii. Dr. Follett is an expert in quarantine research, including for fruit flies. Dr. Mangan is a recognized expert in quarantine research especially with regard to the Mexican fruit fly. He also reviewed the experimental work plan of Dr. Aluja prior to initiation of the study, and the work plan of Dr. Enkerlin who conducted similar research



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on Mexican fruit fly relative to host status for avocado in Mexico 1993-1994. He also provided USDA oversight of Dr. Enkerlin's research over the course of that study and provided input into the ARS review of the results of that research ("**ARS Review of Research Report from Mexico on Host Status of Hass avocado for Anastrepha Fruit Flies**", Ken Vick, National Program Leader, Stored Product Insects and Plant Quarantine, USDA/ARS, 7/21/1994). Dr. Ken Vick's role in the present review was to consolidate the views and comments of Drs. Follett and Mangan and provide a second tier review of the entire subject.

Previous work on avocados, especially Enkerlin, et al., (Status of the "Hass" avocado as host of three species of fruit flies of the *Anastrepha* genus (Diptera: Tephritidae) under induced laboratory and field conditions and also under natural field conditions, Secretariat of Agriculture and Water Resources; Plant Health General Directorate, Mexico National Campaign Against fruit flies, May 1994) established that Hass avocados could become good hosts after harvest but while on the tree were poor hosts for Mexican fruit fly. Clearly there is a fruit maturation process that makes fruit more acceptable to Mexican fruit fly as the fruit ripens. The physiological nature of this switch-over, or when or how fast it happens is not known. It appears from Enkerlin, et al.'s work, however, that the threshold for avocados becoming a good host to Mexican fruit fly happens soon after harvest.

The Aluja et al. manuscript is a thorough study of fruit fly behavior relative to avocado fruit. The Journal of Economic Entomology has accepted it. The purpose of this review was for ARS to determine whether the data presented justify ARS changing its position developed after the Enkerlin et al. study showing that Hass avocado is a poor host of Mexican fruit fly while the fruit is still attached to the tree. Technical comments that follow focus on those data that were critical to making that decision. While we do not take issue with the data presented, we do disagree in some cases with the conclusions that were drawn by the authors.

Aluja et al. distinguish between infestations that occur in caged tests and those that occur in free-living fly populations. The view held by the ARS reviewers of this manuscript is that the use of caged tests are a valid and necessary host status research method. Given the infrequency of oviposition and egg survival in a poor host, the uncertain fruit fly population and the millions of avocados in an orchard, it would be almost impossible to conduct meaningful host status tests without caged tests. Oviposition is a complex and purposeful behavior, not simply a scattering of eggs by gravid females bent on releasing matured eggs. It is known that Mexican fruit fly females can hold their eggs and that even under the best of rearing conditions, many females do not oviposit. Thus, there is no evidence that Mexican fruit fly females were "forced" to oviposit during the short exposure period used by the authors in these tests.

In this study, the flies were "forced" to be in contact with avocado tree limbs and fruit, however the trapping data presented by Aluja et al. showed that this cage situation

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mimicked the situation in the field. In addition, the highest frequency of adult captures in the avocado orchards were during the winter months when fruit were reaching maturity. Interestingly, Oi (Oi, D. H., 1983, The effects of ripeness and skin penetrability on the breeding of the Mediterranean fruit fly, *Ceratitis capitata* (Wied.), and oriental fruit fly, *Dacus dorsalis* Hendel, in the 'Sharwil' avocado. M.S. Thesis, University of Hawaii, Honolulu) and Oi and Mau (Oi, D. H. & R. F. Mau, 1989, The relationship of fruit ripeness to infestation in 'Sharwil' avocados by the Mediterranean fruit fly and the oriental fruit fly (Diptera: Tephritidae). J. Econ. Entomol. 82: 556-560.) were also able to infest Sharwil avocados when Mediterranean fruit flies and oriental fruit flies were caged with Sharwil avocado fruit still attached to the tree (3 infested fruit of 19 with Mediterranean fruit fly and 1 of 21 with oriental fruit fly). Armstrong (1991) discounted this work and said "...forced infestations do not necessarily reflect the true host status of the 'Sharwil' avocado in nature or under commercial conditions" only a few months before fruit flies were found in Sharwil avocados being packed for export to the U.S. mainland.

It seems clear that in the present case, the vast majority of Haas avocado picked from trees and safeguarded after harvest will not be infested with Mexican fruit fly. However, Mexican fruit flies are found in the interior of Haas avocado orchards, they attempt and succeed in ovipositing in fruit on the tree, and in the Aluja et al. study 4 fruit were infested with larvae. The infested fruit were apparently normal in appearance. The reason infestation can occur in a small number of fruit is not known. It is also not known how frequently this happens, whether it is seasonal or whether conditions in some years favor increased incidence. It is the ARS view that the small infestation rate observed in Haas avocado, in the context of other avocado experience, is sufficient to classify Haas avocado as a very poor host of Mexican fruit fly. This is consistent with the decision made for Sharwil avocado in Hawaii in the early 1990's.

It is not an ARS role to take a position on whether low level infestation rate such as seen in the case of Haas avocado poses an important quarantine risk. Nor is it an ARS role to suggest whether mitigation is needed or the type of mitigation required, should APHIS decide one is needed. ARS defers to APHIS' experience and expertise in risk assessment and management and notes that APHIS successfully manages many commodities with quarantine risks (including avocados) entering the U.S. from all parts of the world.

cc:

C. Rexroad, ARS

G. Gordh, APHIS